**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**SCHOOL OF GRADUATE STUDIES**

**DEPARTMENT OF CROP AND SOIL SCIENCES**



# SEED-BORNE FUNGI OF FARMER-SAVED RICE (*Oryza sativa* L.) SEEDS FROM INLAND VALLEYS OF THREE DISTRICTS IN ASHANTI REGION OF GHANA AND THEIR MANAGEMENT

**By**

**JERRY FENTENG ASAMOAH (Bsc. General Agriculture)**

AUGUST, 2012

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE CROP PROTECTION (PLANT PATHOLOGY) DEGREE



**AUGUST, 2012**

## DECLARATION

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

JERRY FENTENG ASAMOAH……………………….. …………………

(PG4240710) SIGNATURE DATE

DR. C. KWOSEH ……………………… …………………

(SUPERVISOR) SIGNATURE DATE

DR. E.MOSES …………………………. ……………………..

(CO-SUPERVISOR) SIGNATURE DATE

DR. C. KWOSEH …………………………. ……………………..

(HEAD OF DEPARTMENT) SIGNATURE DATE

## ABSTRACT

A field survey was conducted in 2011/2012 cropping season in three selected rice growing districts comprising 13 communities to assess the quality of farmer-saved rice seeds and farmers' perception of seed-borne diseases of rice. Majority of smallholder rice farmers in Ashanti Region of Ghana (71 %) saved their own seeds for planting. Few farmers (12%) followed proper storage practices for the seeds which were stored under ambient conditions in nylon fertilizer bags, jute sacks and black polyethylene bags, which were not treated against insect pests. The study also revealed that none of the seed samples was free from seed-borne pathogens and saprophytic fungi. Twenty fungal species comprising 16 pathogens and four saprophytes were identified on seed samples from the three districts. The most prevalent seed-borne pathogenic fungi identified were *Bipolaris oryzae*, *Fusarium verticillioides, F.oxysporum*, *Curvularia lunata and Cercospora* sp. while *Aspergillus flavus, A.niger*, *Rhizopus* sp. and *Penicillium* sp. were the most prevalent saprophytes. Efficacy of aqueous extracts of ginger (*Zingiber officinale*), hot pepper (*Capsicum frutescens*) and lemongrass (*Cymbopogon citratus*) prepared at a concentration of 1g/ml for the management of seed-borne pathogens was studied. The aqueous extracts of ginger, pepper and lemongrass were found to be significantly effective in reducing infection levels of seeds. Ginger extract was the most effective.

## DEDICATION

To my elder brother,Peter Acheampong, my mother, Mrs Dinah Kyei Fenteng, and My dad, Mr Paul Fenteng and my entire family and friends for their inspiration and guidance

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## TABLE OF CONTENT

**CONTENT** **PAGE**

## LIST OF TABLES

**Table** **Page**

## LIST OF FIGURES

**Figure** **Page**

# CHAPTERONE

## INTRODUCTION

Rice (*Oryza sativa* L.) is the grain with the second highest worldwide production after maize (Boumas, 1985). The domesticated rice comprises two species of food crop in the Poaceae ("true grass") family: *Oryza sativa* and *Oryza glaberrima* (Linscombe, 2006). These plants are native to Tropical and Subtropical Southern Asia and Southeastern Africa, respectively (Linares, 2002).

A vast majority of the people in the world consumes rice and it is the second most important cereal in the world today and provides, together with wheat, a large proportion (95 %) of the total nourishment of the world's population. It is the daily food for over 1.5 billion people (Boumas, 1985). The reason for it being so popular is that it is easily digested. Rice occupies a conspicuous position in the world's agrobased economy being the most important food crop that provides considerable calories of energy for more people than any other crop. It accounts for 23 % of the world's supply of calories (FAO, 2005).

Among the major cereals cultivated, rice is the most rapidly growing food source in Africa: between 1985 and 2003, the annual increase in rice production was four percent, while production growth for maize and sorghum was only about 2.4 and2.5 percent, respectively (Kormawa *et al*., 2004).It is estimated that Africa produced an average of 14.6 million tonnes of rough rice per year on 7.3 million hectares between 1989 and 1996 (Traore, 2005).Available data from the Ministry of Food and Agriculture (MoFA) reveal that whilst the estimated national rice consumption stands at 561,400 metric tonnes per year, rice produced locally is 107,900 metric tonnes per year, leaving a gap of 453,500 metric tonnes per year, which has to be imported (Public Agenda, 2009).With a population growth rate of 2.5% and an annual rice demand growth rate of 8.9 %, a supply of 1.6 million tonnes of rice will be needed annually in Ghana by 2015.The country, therefore, has to make serious efforts to increase its production.

Despite these production levels, rice production, however, is affected by production constraints worldwide. Some of the major constraints include unavailability of good quality varieties that are preferred by majority of Ghanaian rice farmers, labour intensity in rice farming, lack of appropriate implements and equipment and weeds infestation. In addition, diseases and pests constitute major constraints to rice production worldwide, Ghana inclusive. Diseases and pests, notably blast, brown spot, sheath blight and bakanae reduce yields significantly in most producing areas in the world and in Ghana. In the field, rice suffers from so many diseases, but the major ones are blast and brown spot. Together with brown spot caused by *Bipolaris oryzae*, blast disease has again been recently listed as one of the serious constraints to rice production in Ghana (Gerken *et al*., 2001). This suggests the need for improved management of blast and brown spot diseases in Ghana if the target set for rice production is to be achieved. Blast can cause losses which are estimated at 11to 30 %, while yield losses caused by brown spot can be as high as 10 to 50 %. Worldwide crop losses caused by bakanae disease may also be as high as 20 % in epidemic cases. All these constraints are prevalent in Ghana. In the West African sub-region, blast is recognized as a primary constraint to rice production causing 3.2-77 % yield losses (Fomba and Taylor, 1994).

Importantly, all or several diseases of rice are seed-borne and seed transmitted and it is recorded that majority of rice farmers use their own saved seeds which may carry a number of important seed-borne pathogens. In Ghana, transmission of diseases could be very high because very few farmers control diseases and most farmers use their own saved seeds for production. Thus, this can contribute to high levels of diseases on the field with resultant high yield losses. High disease pressures and high yield losses are common in systems when farmers do not control diseases and also depend on their saved seeds.

This study was, therefore, conducted to identify the important seed-borne pathogens of rice in some of the major producing areas and develop appropriate control measures to reduce seed-borne pathogens. Controlling seed-borne pathogens would contribute to a reduction in field diseases. This will in turn contribute to improved yields.

The main objective of this study was to identify seed-borne fungal pathogens of rice from inland valleys in major rice producing communities in Ashanti Region of Ghana, farmers' perception and practices, and develop appropriate control measures to reduce these seed-borne fungal pathogens. The specific objectives were:

(i) to determine farmers' perception about seed-borne fungal diseases, farmers' knowledge and practices, the storage conditions and practices employed in the storage of farmer-saved rice seeds and sources of seeds available to smallholder rice farmers.

(ii) identify seed-borne fungi of rice in three selected rice growing districts of Ashanti Region

(iii) to develop appropriate and effective control measure against seed-borne fungi using botanicals

(iv) to determine the effects of treatments on germination of rice seeds.

## CHAPTER TWO

## LITERATURE REVIEW

### 2.1 Importance of rice

Rice is the primary food for half the people in the world, and in many regions, it is eaten with every meal. It has been an important food commodity for most people in sub-Saharan Africa, particularly, West Africa. The consumption of cereals mainly, sorghum and millet has decreased from 61 % in 1970's to 49 % in 1990's while that of rice has increased from 15-26 % over the same period (Rosegrant *et al.*, 2002). Calpe (2002) described rice as a major staple food for the rural population, and mainly cultivated by small-scale farmers in holdings of less than 1 ha. Fageria *et al.* (2003) reported that, rice is that main source of 35-60 % dietary calories consumed by more than 3 billion people and probably the most versatile crop. It is central to the food security of over half the world's population.

Rice is now a major staple food for millions of people in West Africa (Basorun, 2003). Africa's emergence as a big rice importer is explained by the fact that during the last decade, rice has become the most rapidly growing food source in sub-Saharan Africa (Sohl, 2005). Rapid population growth at 2.6 % per annum, increasing urbanization and the relative ease of preservation and cooking have influenced the growing trend in rice consumption. It is utilized mostly at the household level, where it is consumed as boiled or fried or ground rice with stew or soup. The complex carbohydrate in rice digests slowly, allowing the body to utilize the energy released over a long period which is nutritionally efficient (Ebuehi and Oyewole, 2007).

When processed and flavoured with grain concentrates, rice straw may be fed to farm animals (Xian-Xiang, 1991). Rice is easy to prepare, compared to other traditional cereals, thereby reducing the chore of food preparation and fitting more easily in the urban lifestyles of rich and poor alike (Chaudhary *et al.*, 1999).

An estimated 4.4 million hectares are under rice cultivation in West Africa (Somado *et al*., 2008). Total rice paddy production in the sub-region is estimated to be about 6.2 million metric tonnes (Anon., 2008). Nonetheless, the stability in rice prices and rice production is desirable while food security is still a major concern for rice importing nations in the region (Defoer *et al.*, 2003).

**2.2 Rice production levels in West Africa**

Out of the vast available areas, West Africa has the largest planted rice area of about 4.1 million hectares. Africa's emergence as a big rice importer is explained by the fact that during the last decade rice has become the most rapidly growing food source in sub-Saharan Africa (Sohl, 2005).Subsistence rice production in Sub Sahara Africa (SSA) thus, characterized by low external input, low yields, food insecurity, nutrient mining and environmental degradation (Mafongoya *et al*., 2006; Rhodes, 1995; Stoorvogel *et al*., 1993).

In West Africa, where the rice sector is the most important in Sub-Saharan Africa, the situation is particularly critical. Despite the upward trends in international and domestic rice prices, domestic rice consumption is increasing at a rate of 8 % per annum, surpassing domestic rice production growth rates of 6 % per annum. The production-consumption gap in this region is being filled by imports, valued at over US$1.4 billion per year. The share of imports in consumption rose from an average of 43 % from 1991 to 2000, to an average 57 % by 2002–2004 (WARDA, 2005). The Food and Agriculture Organization (FAO) estimated in 2006 that, current rice imports into the West and Central African sub-region had grown to more than 6 million tonnes, costing over $1 billion in scarce foreign exchange each year. The cost of importing rice therefore remains a heavy burden on trade balances in the region.

### 2.3 Rice production in Ghana

Urbanization appears to be the most important cause of the shift in consumer preferences towards rice in Ghana. About 90 % of Ghana's rice is produced in the lowland and hydromorphic ecologies (Otoo, 1994). However, the lowland system is more dominant due to the erratic rainfall regimes of northern Ghana. The demand for rice in Ghana has been soaring and was partly as result of increasing population growth, increased income levels, rapid urbanization and associated changes in family occupational structures. While rice is very much a cash crop for small-to mediumscale farmers in some countries, it is more of a subsistence crop in the Northern Region of Ghana where most of the rice is produced.

In Ghana, 75 % of the total production of rice in 1999/2003 was from upland, hydromorphic and lowland ecosystems (SRID-MOFA, 2007). Between 1989 and 1996, there was a steady increase in rice production at the rate of 13% per annum due to area expansion and yield increase from 0.9 to 2.4 kg/ha (MOFA, 2009). Total domestic production of milled rice in 2007 was 111,000 metric tonnes and the production available for human consumption was 89,000metric tonnes (SRID-MOFA, 2007). Estimated national consumption of milled rice in 2007 was 335,000 metric tonnes, and this was calculated based on the 2000 census of population of 18.9million and a growth rate of 2.7 % (SRID-MOFA, 2007). In the Government's bid to compensate for the deficit, it was estimated that US$ 500 million was spent on the importation of rice into the country in 2007 though about 200,000 metric tonnes also came in as food aid in the same year (MOFA- SRID, 2007).

In Ghana, the total rice consumption in 2005 amounted to about 500,000 metric tonnes which is equivalent to per capital consumption of 22 kg per person (Tomlins *et al.*, 2005). Irrigated rice yields in Ghana are known to vary from 3.5 t/ha to 7 t/ha with an average yield of 4.6 t/ha on formal irrigation schemes (FAO, 2005).

Despite the increases in rice production, importation of rice continues to increase reaching the tune of $200 million per annum. Ghana depends largely on imported rice to make up the deficit in rice supply. The self-sufficiency ratio of rice in Ghana has declined from 38 % in 1999 to 24 % in 2006 (Andriesse and Fresco, 1991). It is the government's objective to reduce rice importation by 30% by increasing local production.

### 2.4 Global economic importance of rice

About 800 million people are suffering from malnourishment and hunger worldwide, thus creating the need for a sustainable increase in rice production to improve global food security and contribute to poverty alleviation (Badawi, 2004). In countries where rice is the staple food, it plays a very important part in food security and socioeconomic development. Rice cultivation is the principal activity and source of income for millions of households around the globe, and several countries of Asia and Africa are highly dependent on rice as a source of foreign exchange earnings and government revenue (IRRI, 2009). Additionally, rice crop vitality can be seen in its nutrition to much of the population in Asia, Latin America and the Caribbean, and Africa. Rice is, therefore considered a strategic commodity in many countries and is, consequently, subject to a wide range of government controls and interventions

(Calpe, 2002).

Rice has been playing a very important role in economic, politic and social aspects in everyday life in many African countries. Rice is the staple food of a growing number of people in sub-Sahara Africa and from 1961 to 2003 consumption increased at a rate of 4.4 % per year (Kormawa *et al*., 2004).

### 2.5 Economic importance of rice in Ghana

Rice is estimated to contribute 15 % of the agricultural gross domestic product (AGDP) of Ghana and covers 45 % of all area planted to cereals. This sector of agriculture provides employment for a lot of rural dwellers. Imported rice is estimated to account for more than 50 % of all rice consumed in the country (Berisavljevic *et al.,* 2003). Local production of rice hardly meets the annual demand of Ghana (Takoradi, 2008).

In the Vision 2020 perspective plan of Ghana, rice production is expected to play a key role in achieving national food security, alleviating rural poverty and contributing to the overall economy through import substitution and conservation of foreign exchange. According to the Millennium Development Authority on economic growth and poverty reduction (MOFA, 2005), rice accounts for nearly 13% of total cereal consumption in Ghana.

### 2.6 Sources of seeds to smallholder farmers

Of all farm inputs, high quality adapted seeds and planting materials exert the most profound influence on agricultural productivity. A wider appreciation of the importance of quality seeds and their crucial role in agricultural and, thus, human development cannot be over-emphasized (Lanteri and Quagliotti, 1997; Cromwell *et al.,* 1993). However, most farmers in sub-Saharan Africa do not buy seeds. They save their own or trade with other farmers. The major reasons assigned to this situation are agronomic and economic in that the saved variety is the best suited to the local soil and climate and it saves money (Anon., 2001). Clottey *et al.* (2009) conducted a survey on some tomato farmers in Ghana that revealed some farmers do not realize the economic benefit of investing in good seed, since the fruit prices on the market are the same irrespective of seed quality. Thus, making farmer-saved and farmer-traded seed to be the dominant source of seed for 80-90 % of farmers in sub-Saharan Africa (Walker*et al.,* 1997 and Almekinders *et al.,* 1994).

### 2.7 Constraints to rice production

Since 1990, rice production has increased at a lower rate than the population. This deceleration in the growth of rice production is a cause for concern in terms of world food security. Demand for rice in West Africa has been growing at the rate of 6 % per year since 1973 (Nwanza, 1996). Increased consumption is due both to population growth and to the increased proportion of rice in the West African diet. In an attempt to keep pace with demands, production of rice in West Africa has been expanding rapidly, growing at 5.1 % per year, faster than any of the other principal staple food crops.

Despite the growth in regional production already achieved, imports of rice have grown at the alarming rate, averaging 9 % a year for two decades. However, since 1995, international rice prices have declined markedly (Calpe, 2003), while prices of production inputs such as fertilizers, other agro-chemicals, labour, fuel, and rice machinery and equipment either increased or at best remained unchanged. These factors have led to an increase in production costs and subsequently, a sharp reduction in the return from rice production. This has been one of the major causes of poverty and hardship for many small farmers in developing countries.

As a low-input system, upland ecosystems tend to not use fertilizer and rely solely on rain. Under these conditions, diseases are considered a major problem as well. Early maturing progenies from interspecific crosses between *Oryza glaberrima* and *O. sativa*, named New Rice for Africa (NERICA), will give farmers the chance to grow rice in areas having limited rainfall. By using fertilizer and controlling pests, lowland areas have the potential to produce far greater yields than the upland ecosystem (WARDA, 1993).Unlike more developed regions of the world, insects and diseases result in a larger drain on rice yields and the problems may persist longer.

Weed competition remains the most outstanding yield-reducing factor, followed by rice blast caused by *Pyricularia oryzae* Cav., soil acidity and general soil infertility. Heavy weed competition may lead to total crop failure. Barnyard grass (*Echinochloa crus-galli* L.) is the dominant weed in lowland rice production. With the increased adoption of direct seeding methods, weedy rice (*Oryza* sp.) has become another major weed in rice production (Ferrero, 2003; Pulver and Nguyen, 1999; Catal`a, 1995).

Virmani (1979) reported iron toxicity exists in many West African countries, including Benin, Burkina Faso, Côte d'Ivoire, Liberia, Nigeria, Senegal and Sierra Leone where yield losses resulting from toxicity range from 12 to 88 %. Where nontolerant lines are grown in such conditions, total crop failure may result.

**2.8 Diseases affecting rice production**

Diseases and their impact on rice production have increased in importance over time. Rice production is affected by diseases through reduction in yield caused by viral, bacterial and fungal pathogens attack. Most of the major diseases of rice are seedborne (Fakir *et al*., 2002). Rice suffers from more than 60 different diseases (Ou, 1985).

Seed-borne diseases cause enormous losses to our crop (Fakir *et al.*, 2002). Most of the diseases of rice are carried though seed and cause enormous losses to the crop.

Fungi, including *Alternaria alternata* (fr.) Keissl, *A. padwickii* (Ganguly) Ellis, *Aspergillus niger*, *Curvularia oryzae* (Bugnic.), *C. lunata* Wakker) Boedijn., *Drechslera oryzae* (Breda de Haan) Shoem., *Fusarium verticillioides* (teleomorph Gibberella moniliformis), *F. semitectum*, *F. oxysporum* f. sp. cubense (Foc), *F. solani* f. sp. pisi, *Pyricularia oryzae* Cav.and species of *Phoma,Cercospora*, *Chaetomium*, *Sclerotium*, *Penicillium*, *Myrothecium* and *Colletotrichum* have been isolated from seeds of different varieties of rice (Javaid *et al*., 2002; Wahid *et al*., 2001). About 10% yield loss of rice may be incurred annually due to theseseed-borne diseases. According to Nsemwa and Wolffhechel (1999), Agarwal *et al*. (1989) and Dharam Vir *et al*. (1971), the most important and widely distributed seed-borne fungal diseases of rice are blast (*Pyricularia oryzae)*, brown spot (*Bipolaris oryzae*), bakanae (*Fusarium verticillioides*) and stackburn disease (*Alternaria padwickii*).

Rice blast is the most serious disease found in the extensive rice areas of Latin America, Africa, and Southeast Asia and is a worldwide problem in rice production. Rice blast disease is a significant constraint to global food security and agricultural trade (Leong, 2004). Blast can affect all stages of crop growth and any organ of the plant such as leaf, sheath, neck, panicle, rachis, stem node and grains. Reported yield losses range from 40 – 75 % and highest losses occur when infection occurs at young or flowering stages.

In the West African sub-region, blast is recognized as a primary constraint to rice production, causing 3.2-77.0 % yield losses (Fomba and Taylor, 1994). In Ghana, rice production is constrained by a number of biotic factors including diseases such as blast, brown spot, bakanae, stackburns, narrow leaf spot and false smut. The most prevalent among these diseases are blast and brown spot. Rice blast was listed as an important disease in Ghana by Clerk (1974) and Oduro (2000). Various reports by Twumasi (1996, 1998), Twumasi and Adu-Tutu (1995), Nutsugah (1997 a, b) and Nutsugah and Twumasi (2001) have identified the blast disease of rice as a serious threat to rice production in Ghana. Together with brown spot, blast disease has been listed as one of the serious constraints to rice production in the country (Gerken *et al*. 2001).

Brown spot has also been reported in all rice-growing areas in the world. It is especially common in rainfed (Singh and Singh, 2000) and upland areas (Gupta and O'Toole, 1986). Brown spot has been historically largely ignored as one of the most common and most damaging rice diseases. Yet, the fact that brown spot is the "poor rice farmer' disease (Zadoks, 2002) anywhere the crop encounters drought, macronutrient deficiency (Ou, 1985), or both, actually tells much more of the importance of the disease. The disease can occur at all crop development stages. The disease causes seedling blight, with small, circular, yellow brown or brown lesions that may girdle the coleoptile and distort primary and secondary leaves (Webster and Gunnell, 1992). Brown spot causes both quantitative and qualitative losses. Surveys showed that brown spot causes a 5% yield loss across all lowland rice production in South and Southeast Asia (Savary *et al*., 2000).

**2.9 Seed-borne fungal pathogens of rice**

Seed lot certification is an important requirement in the seed industry because of the effects of seed quality on crop yield (Singh and Maheshwari, 2001; Kumar *et al.,* 2004). High quality seed enhances the raising of healthy plants and establishment of optimal plant population in the field (Doijoe, 1988).

About 20 species of fungal pathogens are detected on rice seed at any one time (Mew *et al.,* 2002). Several seed-borne fungal pathogens such as *B. oryzae, A. padwickii, F. verticillioides, F. pallidoroseum, M. oryzae,* and *Sarocladium oryzae* have been isolated from rice seeds. These pathogens caused lower germination of seeds and transmitted diseases from seed to rice plants (Huynh *et al*., 2001). Marthur and Neergaard (1970) reported that a myriad of seed-borne fungi that caused serious diseases of rice in nurseries, fields and storage are seed-borne. Other fungal pathogens of rice include: *Alternaria padwickii, Curvularia lunata, Fusarium verticillioides* and *Cladosporum* sp. (Bankole, 1996). Mehrota and Agarwal (2003) reported that these fungi could retard seed germination through softening and necrosis of tissues. They have also been found to be associated with seed viability, wilting of plants and stem flaccidity. *Fusarium oxysporum* causes root rot while *Alternaria padwickii* causes

Stackburn of rice. Conversely, storage fungi such as *Aspergillus flavus* and

*Aspergillus niger*are not pathogenic (Bankole, 1996; Harman and Pfleger, 1974; Kulik, 1973) and, therefore, have no effect on germination of the seeds. However, they are associated with damaged seed. Agarwal and Sinclair (1995) regard these fungi as storage fungi that can be involved in deterioration during storage.

Seed-borne fungi are of considerable importance due to their influence on the overall health, germination and final crop stand in the field (Agarwal, 1981). The infected seeds may fail to germinate, or transmit disease from seed to seedling and/or from seedling to growing plant (Fakir *et al.,* 2002). The presence of disease pathogens on seeds is also one of the causes of low seed viability (Elias *et al.*, 2004; Bewley and Black, 1994).

According to Anjorin and Mohammed (2009), the effects of fungi on seeds include poor germination, less vigorous seedlings and low yield. However, the effect of seedborne pathogen on seed and seedling production can go unnoticed until extreme germination failures have occurred (Epners, 1964*).*

In terms of seed health, Hemanth *et al.* (2007) revealed that farmers' saved paddy, sorghum and cowpea seeds were of poor health status, because the seeds were infected with 28 different genera of fungi. The storage structure was implicated as a major factor responsible for the prevalence of the seed mycoflora (Hemanth *et al.,* 2007). In Ghana, about 25 % of farmers attributed poor field germination of cowpea to poor seed quality (Walker *et al.,* 1997). Similarly, the poor field germination of rice was attributed to the quality of farmer-saved seeds (Haque *et al.,* 2007). Mew *et al.* (1994) reported that the use of good quality seeds can lead to a yield increase of 520%.

### 2.10 Control of seed-borne fungal diseases of rice

Rice is one of the world's most important cereal crops and its protection from disease is vital to the many millions dependent on it as their staple food. However, with increasing demand for world rice supplies, there has been awakening interest to maximize production using improved varieties, high fertilizer application and other intensive cultural practices. High cultural regimes, therefore, have led to a great increase in the occurrence and severity of diseases affecting it in several countries.

Rice is subject to several destructive diseases. Therefore, dependence on host resistance alone has been found to be unreliable and disappointing. Chemical control offers greater promise and constitutes an important weapon in reducing crop losses caused by rice diseases. Seed treatment is the safest and the cheapest way of control of seed-borne fungal diseases and to prevent biodeterioration of grains (Bagga and Sharma, 2006; Chandler, 2005). Agarwal *et al*. (1989) and De Waard *et al*.(1993) suggested disease management through seed treatments as an integral component of rice crop production to avoid unacceptable crop losses and also to meet the challenge posed by feeding the growing world population. De Waard *et al*. (1993), Bateman *et al*. (1986) and Dharam Vir *et al*. (1971) have reported the use of fungicides in controlling seed-borne diseases of rice.

## 2.11 Use of botanicals and chemicals in controlling seed-borne fungal diseases

Seed-borne fungal pathogens of rice are of major importance and promote substantial losses (Agarwal *et al*., 1989).Fungal diseases are known to cause great damage all over the world. Different species of *Alternaria*, *Aspergillus, Ceratobasidium, Cercospora, Cochliobolus, Curvularia, Dreschslera, Fusarium, Gaeumannomyces, Microdochium, Penicillium, Pyricularia, Pythium, Rhizoctonia, Rhizopus, Sclerophthora, Trichoderma* and *Tricoconella* are most common associates of seeds all over the world, causing pre and post-infections and considerable quality losses such as seed abortion, seed rot, seed necrosis, reduction or elimination of germination capacity, seedling damage and their nutritive value have been reported (Kavitha *et al.*,2005; Miller, 1995).

Even though effective and efficient control of seed-borne fungi can be achieved by the use synthetic chemical fungicides, the same cannot be applied to grains for reasons of pesticide toxicity (Harris *et al*., 2001). Chemical fungicides cause serious environmental problems and are toxic to non-target organisms (Anon., 2005). The toxic effect of synthetic chemicals can be overcome, only by persistent search for new and safer pesticides accompanied by wide use of pest control methods, which are ecofriendly and effective (Mohana *et al.*, 2011).

Green plants represent a reservoir of effective chemotherapeutants and can provide valuable sources of natural pesticides (Balandrin *et al.*, 1985). Leaf extracts of various plants are known to possess antimicrobial activity (Suhaila-Mohamed *et al.*, 1996; Charjan, 1995). Extracts of many plants have been reported to exhibit antifungal properties under laboratory trials (Mohana *et al*., 2008; Parekh *et al*., 2006; Aliero and Afolayan, 2006; Buwa and Staden, 2006; Ergene *et al*., 2006). Exploitation of plant metabolites in crop protection and prevention of biodeterioration caused by fungi appear to be promising. There is evidence that several plant species possess antifungal and antibacterial properties (Dubey *et al*., 2009; Ogbo and Oyibo, 2008; Hasan *et al.*, 2005). Evaluation of botanicals against blast disease and some seed-borne pathogens of rice have been reported (Nguefack *et al.*, 2005; Kagale *et al.*, 2004; Amadioha, 2000)

The use of plant extracts as seed treatment has produced good results against various soil-borne fungi such as *P. aphanidermatum* and *R. solani* (Khan *et al.*, 1974), *Fusarium oxysporum* (Kannaiyan and Prasad, 1981) and *Colletotrichum atramentarium* (Singh, 1986). Some plant extracts act as contact fungicides; some disrupt cell membrane integrity at different stages of fungal development, while the others inactivate important enzymes and interfere with metabolic processes (Singh, 1986). According to Adityachaudhury (1991), the use of plant extracts and phytoproducts is gaining attention due to their biodegradability, low toxicity and minimum residual toxicity in the ecosystem. Accordingly, natural products are considered to control fungal diseases in plants as an interesting alternative to synthetic fungicides due to their comparatively smaller negative impact on the environment (Ogobo and Oyibo, 2008).Natural plant extracts are important source of new agrochemicals and non-selective pesticides for control of plant diseases (Tripathi and Dubey, 2004).Plant products, particularly spices and extracts of various plant parts, have been used extensively as natural antimicrobials and antioxidants. Alam *et al*. (2002) reported high levels of inhibition of spore/conidia germination of some fungal species using extracts of rice, wheat straws and tobacco leaf. Many reports revealed that, plant metabolites and plant based pesticides appear to be one of the better alternatives as they are known to have minimal environmental impact and danger to consumers in contrast to synthetic pesticides (Gottlieb *et al.*, 2002; Varma and Dubey, 1999; Harborne, 1998).

## 2.12 Ginger

Ginger (*Zingiber officinale* Roscoe *auth.*) is one of the spices reported to have some anti-fungal activities. The nutrient composition varies with the type, variety, agronomic condition, curing methods, drying and storage conditions (Govindarajan, 1982). In the fresh ginger rhizome, the gingerols were identified as the major active components and gingerol [5-hydroxyl] -1- (4-hydorxy-3-methoxyphenyl) decan-3- one is the most abundant constituent in the gingerol series (Govindarajan, 1982). The rhizome contains 3-6 % fatty oil, 9 % protein, 60-70 % carbohydrates, 3-8 % crude fiber, about 8 % ash, 9-12 % water and 2-3 % volatile oil (Govindarajan, 1982). Kuhn and Hargreaves (1997) observed that substances found to be fungicidal in-vitro in almost all cases kill the fungus in-vivo. Plants with such fungicidal properties include *Zingiber officinale* and *Xylopia aethiopica* (Dunal) (Maurice, 1993). Ginger root extract has microbial action at levels equivalent to 200mg/ml of the spice. Ginger inhibits *Aspergillus flavus*, a fungus known for the production of Aflatoxin, a carcinogen (Nanir and Kadu., 1987).Fresh ginger juice showed inhibitory action against *Aspergillus niger, S. cerevisiae, Mycoderma* spp. and *Lactobacillus acidophilus* at 4, 10, 12 and 14 %, respectively at ambient temperatures (Meena, 1992).

## 2.13 Lemongrass

Lemongrass (*Cymbopogon citratus* (DC.) Stapf.) belongs to the grass family, Poaceae (Valencia and Myers, 1998). Fresh *C. citratus* contains approximately 0.4% volatile oil. The oil contains 65 % to 85 % citral, a mixture of two geometric isomers, geraniol and neral. Related compounds geraniol, geranic acid, and nerolic acid have also been identified (Masuda *et al.*, 2008; Torres, 1993). Other compounds found in the oil include myrcene (12 % to 25 %), diterpenes, methylheptenone, citronellol, linalol, farnesol, other alcohols, aldehydes, linalool, terpineol, and more than a dozen other minor fragrant components (Kasumov and Babaev, 1983). Non-volatile components of *C. citratus* consist of luteolins, caffeic acid, fructose, sucrose, octacosanol, and others (De Matouschek, 1991). Proximate analysis of lemongrass also revealed the presence of potassium, zinc, iron and manganese (Livestrong.com, 2010). Lemongrasses as well as many other plants have been successfully used to control important seed-borne fungal pathogens (Amadioha, 2000). In Nigeria, lemongrass powder and essential oil have been successfully used to protect cowpea and maize against storage fungi and *Macrophomina phaseolina* (Tassi) Goid (Adegoke and Odesola, 1996). Aqueous extract of lemongrass was also effective against seed-borne fungal pathogens of melon (Bankole and Adebanjo, 1995). Somda *et al.*, (2007) controlled *Fusarium verticillioides* and other seed-borne pathogens of sorghum with lemongrass extract.

### 2.14 Hot pepper

*Capsicum frutescens* (L.) exists as an annual herbaceous vegetable or perennial shrub of the Solanacae family (Amusa *et al*., 2004).It is a spice grown in both tropical and subtropical regions (Than *et al*., 2008). Pepper is also suitable for the diets of the obese and is useful in the control of cancer of the stomach and colon (PamplonaRoger, 2007). Hot peppers are low in sodium, cholesterol free, rich in vitamins A and

C, and are a good source of potassium, folic acid and vitamin E (Than *et al.*, 2008). Fresh green hot peppers contain more vitamin C than citrus fruits and fresh red hot has more vitamin A than carrots (Than *et al.*, 2008). Capsicum fruits are used in sauces, soups, stews and generally as a flavouring agent (Amusa *et al*., 2004). The different varieties of pepper provide income for women and children who cultivate it in large quantities (Amusa *et al*., 2004).Pepper extracts have been shown to reduce aflatoxin production in *A. parasiticus* IFO 30179 and *A. flavus* var *columnaris* S46 (Ito *et al*., 1994).

### 2.15 Factors affecting seed germination and occurrence of fungal pathogens

Quality characters of seed, such as seed germination, moisture content, seed discolouration and seed-borne fungal prevalence have long been known to be influenced by various factors during storage. There are several factors that affect seed germination and the occurrence of fungal pathogens. These include:

#### 2.15.1 Moisture content

High seed moisture is reported to affects seed quality. Between 40 – 60% moisture content, metabolic activities increase and seed germination is triggered off resulting in the death of the embryo. An earlier report indicated that seed with hard seed coat prevented oxygen and moisture entry into seed and prevented autoxidation of linoleic and linolenic acids which are responsible for degradation of cellular organelles (Cantliffe, 1998). The field fungi such as *Alternaria*, *Cladosporium*, *Curvularia*, *Fusarium* and *Helminthosporium* invade seeds as they are developing on the plants in the field or after they have matured, but before they are harvested (Christensen and Kaufmann, 1965). These fungi usually do not continue to grow in grains after harvest, but may remain alive for years in grains stored at low moisture content and low temperature (Christensen, 1963).

The storage fungi, mainly comprising several species of *Aspergillus* and *Penicillium,* do not invade grains to any appreciable degree or extent before harvest (Tuite, 1961), but they can cause severe discolouration of seed in storage resulting in germination failure, discoloured or otherwise damaged embryos or whole seeds, and production of mycotoxins that constitute a health hazard for man and animals (Dharam Vir, 1986; Mehrotra, 1983; Bilgrami and Sinha, 1983; Christensen and Kaufmann, 1979 ;Dharam Vir, 1974). Each species or group of species of *Aspergillus* has its own rather sharply defined lower limit of moisture content usually between 13 and 18 % for invasion of stored grains.



### 2.15.2 Storage

Seed is stored with the express objective of maintaining quality for both consumption and planting purposes (Agrawal, 1995; George, 1985; FAO, 1981). Chin (1988) proposed that pertinent questions concerning the principal aims of storage, quantity to store and length of storage must diligently be considered before embarking on any seed storage programme. Hong and Ellis (1996) reported that seed storage is an age old practice that started with the inception of agriculture when humans began to domesticate plants. Reviewing methods of storage, the University of Greenwich (1999) recognised three types: traditional, improved traditional and modern types. With particular reference to West Africa, cribs, baskets, metal tanks, mud silos, underground pits and jute cotton bags are common methods of storage. Choice of the method to use for storing seed depends on the kind of seed (FAO, 1981).

It is contested that some storage structures do not preserve seed quality. According to Singh (1990), in Africa and China traditional storage structures used in storing maize, rice, wheat, millet and chickpea include; mud, dung, bamboo, and rice straw silos. The author observed that high humidity and poor storage practices associated with these kinds of storage facilities provided congenial environment for microbial attack; the dominant species being *Aspergillus* spp. and *Penicillium* spp. Olakojo *et al.* (2007) observed that cowpea seed in plastic containers stored better than when put in tin and earthen containers under the same conditions and contended that nylon sacks should not be used in order to avoid complete damage of the seeds.

### 2.15.3 Temperature

FAO (1981) reported that farmers in the developing world still store their produce including seed under the ambient environment. Chin (1988) found that storage under ambient conditions is very practical in the tropical world where the relative humidity is low. However, seed is hygroscopic and would develop equilibrium moisture content with that of the physical environment where it is placed (Copeland and McDonald, 2001). In Japan, Juliano *et al*. (1990) reported that Japanese brown rice attained equilibrium moisture content with the environment when stored under ambient conditions.

However, storage under ambient conditions has been observed to affect seed quality in general and germination in particular. Basu (1990) indicated that serious losses of viability have been reported from areas (experiencing low relative humidity and temperature) believed to have suitable or conducive climate for the production and storage of seed.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Study approaches

The study approaches comprised (i) field survey and (ii) laboratory experiments. The field survey was conducted in 2011/2012 cropping season to find out the sources of seeds available to rice farmers, the storage practices employed by these farmers,

farmers' perception on seed-borne diseases and disease control practices in three selected rice growing districts in Ashanti Region of Ghana.

In all, 13 communities in three selected districts were surveyed. These were EjisuJuaben District: Besease, Ampabame and Nobewam, Ahafo-Ano South District: Amoakokrom, Essienkyem, Camp, Barniehkrom, Nsutem and Asuodei, and Afigya Kwabre District: Aponoponoso, Abankroso, Nyabesu Nkwanta and KY.

The laboratory experiments were carried out to identify seed-borne fungal pathogens of rice in the three selected districts and develop an effective control measure.

### 3.2 Field survey: Assessment of rice farmers' perception on seed-borne diseases and disease control practices

A field survey was conducted from June to August, 2011 in the three selected rice growing districts in Ashanti Region, using a structured questionnaire to gather information from rice farmers. Questionnaires were issued randomly to rice farmers. Information gathered included names of rice varieties grown, source (s) of seeds, seed storage practices, storage packaging material, farmers' knowledge on seed-borne diseases and knowledge about varieties grown. A total of 66farmers were randomly selected and interviewed in the study areas.

#### 3.2.1 Collection of rice seed samples

A total of 60 farmer-saved rice seed samples were collected from 60 farmers randomly selected from the 13 communities in the three selected districts (EjisuJuaben,Ahafo-Ano South and Afigya-Kwabre Districts). The sampled seeds were stored in brown envelopes labelled, sealed, and stored in refrigerator.

### 3.3 Assessment of seed quality of farmer-saved rice seed samples

#### 3.3.1 Experimental locations

Seed health test was conducted at the Seed Pathology Laboratory of Council for Scientific and Industrial Research-Crops Research Institute, Kumasi.

#### 3.3.2 Seed health test of the sampled farmer-saved rice seeds

The seed health test was done, using the blotter method (Marthur and Kongsdal, 2003). Two hundred rice seeds were randomly taken from the seed component of each sample for the health test. Three pieces of filter paper were soaked in sterile distilled water and placed in a 9-cm Petri dish. Twenty-five seeds were plated in each Petri dish. Eight plates were used for each sample. The seeds in the Petri dishes were incubated at 20 + 2°C under alternating cycles of 12 h near ultraviolet (NUV) light and darkness for seven days. After incubation, the seeds were examined under Stereo microscope to record the incidence of different seed-borne fungi. Where direct identification of seed-borne fungi was difficult, isolates were plated on PDA. Spores or conidia characteristics were used for fungal identification using descriptions of

Marthur and Kongsdal (2003).

### 3.4 Evaluation of Ginger (*Zingiber officinale*), Hot pepper (*Capsicum frutescens*) and Lemongrass (*Cymbopogon citratus*) for the control of seed-borne fungi of rice

#### 3.4.1 Rice sample used for the evaluation of the botanicals

Rice seed sample with the highest incidence of seed-borne fungal pathogens among the three districts was selected for the control studies, using botanicals. This rice seed sample was selected from Ahafo-Ano South District.

### 3.4.2 Plant material and aqueous extract preparation

Aqueous extracts (cold water extracts) were prepared from *Z. officinale, C. citratus* and *Capsicum frutescens*. Extracts were prepared from the leaves of lemongrass, fruit of hot pepper and rhizome of ginger. Plant materials were thoroughly washed with tap water. A weight of 200 g of each plant material was blended separately using an electric blender (Sabichi table blender, SB-1101-14799) and the residue was poured into Erlenmeyer flask containing 200 ml cold distilled water. The resulting stock was sieved, using four layers cheese cloth to remove debris. The debris-free stock was used in the study.

### 3.4.3 Treatments

The treatments used in the evaluation were the aqueous extracts of ginger, lemongrass and hot pepper extracted as previously described. Mancozeb and sterile distilled water served as the positive and negative checks, respectively. Seeds not treated with the plant extracts and chemical fungicides were used as control.

### 3.4.4 Seed treatment and health studies of treated seeds

Rice seed sample with high infection of fungal pathogens from the Ahafo-Ano South District were treated with each of the prepared plant extracts by soaking the seeds in them for 1, 2, 5 and 24 h. Rice seeds were also soaked in the chemical fungicide Mancozeb at 0.25 % of seed weight and in sterile distilled water for 1, 2, 5 and 24 hours. Rice seeds not treated with the extracts, Mancozeb (ethylene bisdithiocarbamate), a synthetic fungicide and sterile distilled water were also used as control. Seed health test was also conducted on the untreated seeds to assess the health status of the seeds before treatment. Treated seeds were collected separately on blotter sheets and air-dried in a Lamina air flow chamber for 60 min. Seed health testing was performed, using the standard blotter method described by the International Rules for

Seed Testing (ISTA, 1985).Seed-borne fungi were identified on treated seeds, using description book of Mathur and Kongsdal (2003) and Agarwal *et al.* (1989). Two hundred seeds of 50 seeds per replicate were used for each treatment. Completely Randomized Design (CRD) with four replications was used. The incidence of fungi and percent germination of the seeds were observed after seven days of incubation at room temperature.

### 3.4.5 Determination of incidence of fungi and per cent germination

The number of seeds infected by fungi was recorded for each sample and divided by the total number of seeds tested, multiplied by 100 % to determine the incidence of fungi. Per cent germination was determined by the blotter method. Two hundred seeds per treatment (50 seeds per replicate) were used for germination test. Seeds were treated as described above and placed on blotters, arranged in CRD to determine percent germination. Untreated seeds were also subjected to similar germination test to serve as control. Germinated seeds were counted on 7$^{th}$day to evaluate germination percentage (ISTA, 1985).The number of seeds germinated were counted and divided by the total of seeds tested, multiplied by 100 % to determine the per cent germination.

### 3.5 Data analysis

The Genstats statistical package (2007) was used to analyse the data and means were separated by least significant difference (lsd). However, count data on incidence was transformed by the square root transformation$\left[\sqrt{(x+0.5)}\right]$before analysis.

# CHAPTER FOUR

# 4.0 RESULTS

## 4.1 Surveys: Farmers' perception about seed-borne fungal diseases, storage containers and practices employed in the storage of farmer-saved rice seeds

### 4.1.1 Sources of seeds of the smallholder rice farmers in the three selected inland valley rice growing districts

Seventy-one per cent of farmers save their own seeds for planting in the following season (Fig.1).Also, 15 % of farmers obtained seeds from neighbours/friends while 7, 5 and 2 % obtained seeds from NGOs, local market and Agro-dealers, respectively. These farmers save their own seeds because they do not have access to certified rice seeds and it is also costly for them to buy if seeds are available.

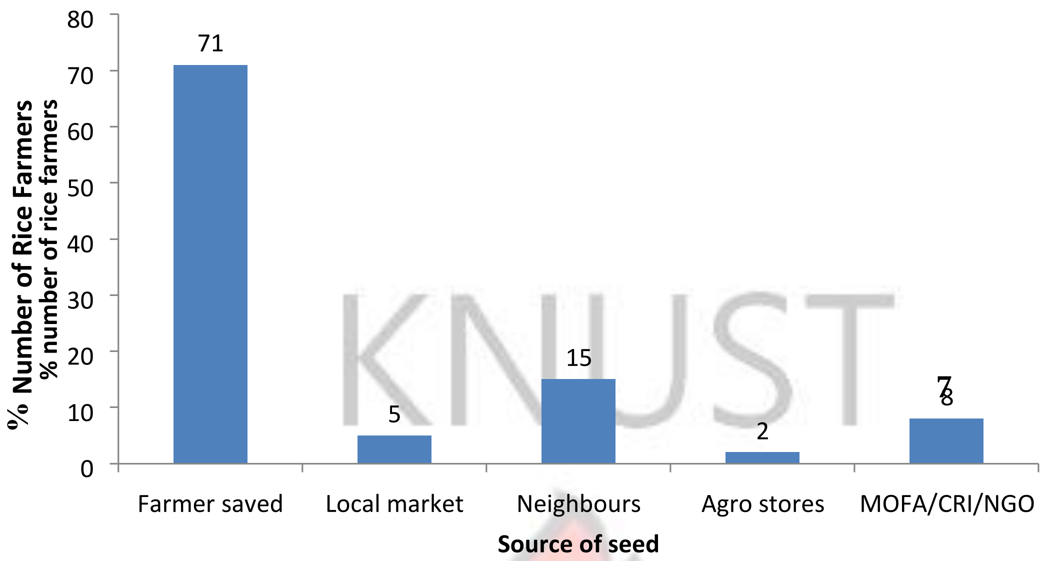


Figure 1: Distribution of Sources of seeds to smallholder rice farmers in the three selected districts

### 4.1.2 Farmers' knowledge on rice varieties cultivated

Majority of the farmers (72 %) knew the names of the varieties they cultivated, while 20 % did not know the names of the varieties they were planting (Fig. 2). Eight per cent of farmers were not sure of the names of varieties they cultivated. Some of the rice varieties mentioned by the farmers were Jasmine 85, Sikamoo, Uncle Bens, Vita 7 and Lapete.

The most cultivated rice varieties were Jasmine 85, Lapete and Sikamoo. According to these farmers, Jasmine 85 and Lapete were early maturing while Sikamoo was more resistant to harsh conditions such as drought and flooding as well as resistant to pests and diseases even though was not early maturing. Jasmine 85 and Lapete were said to have good aroma and are marketable according to them.

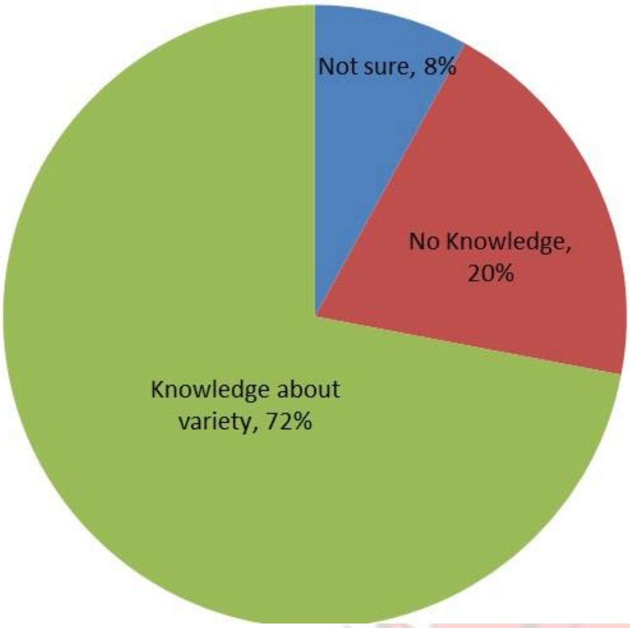


Figure 2: Percent distribution of farmers' knowledge of rice varieties cultivated in the three selected districts in Ashanti Region

**4.1.3Storage practices and conditions employed by rice farmers in the three selected inland valley rice growing districts**

**4.1.3.1 Storage containers and environment used by rice farmers**

Majority of rice farmers in the three selected districts stored their rice seeds in nylon fertilizer sacks, followed by jute sack in their rooms (Table 1). The least used storage container was polyethene bags. The rice seeds in their various containers were all stored under ambient environment.

**Table1: Storage materials and environment used by rice farmers in the three selected districts of Ashanti Region**

| Storage container | Per cent farmers | Storage condition |
|---|---|---|
| Nylon fertilizer sacks | 53 | Ambient temperature |
| Cocoa jute sacks | 44 | Ambient temperature |

| | | |
|---|---|---|
| Polyethene bags | 3 | Ambient temperature |
| Total respondents | 100 | |

#### 4.1.3.2 Seed treatment before storage and sowing of farmer-saved rice seeds

Majority of rice farmers (88 %) did not treat their rice seeds before storage (Table 2). However, 12 % of them treated their rice seeds, mostly with rodenticides. Majority of rice farmers (94 %) did not treat their seeds before sowing (Table 2). Reasons assigned for not conducting seed treatment included lack of technical knowhow and also they thought enough sunshine during drying was enough treatment. However, 6 % of the farmers treated their saved seeds with rodenticides before sowing (Table 2).

**Table 2: Percent farmers' seed treatment potential prior to storage and before sowing**

| Treatment | % Rice farmers response | |
|---|---|---|
| | Prior to storage | Before sowing |
| No seed treatment | 88 | 94 |
| Seed treatment with rodenticides | 12 | 6 |
| Total respondents | 100 | 100 |

#### 4.1.3.3 Duration of storage of farmer-saved rice seeds in the three selected districts of Ashanti Region

Majority of rice farmers in the three selected districts stored their seeds for three to five months (Table 3). Twenty seven per cent of farmers stored their seeds for 9-12 months whiles 21 and 14 % of farmers stored their seeds for six to seven and one to two months, respectively. Lack of irrigation facilities and erratic rainfall patterns at their locations determined when their stored seeds would be planted.

**Table 3: Duration of storage of farmer-saved rice seeds in the three selected districts of Ashanti Region**

| Duration of storage (months) | % Rice farmers |
|---|---|
| 1-2 | 14 |
| 3-5 | 38 |
| 6-7 | 21 |
| 9-12 | 27 |
| Total respondents | 100 |

**4.1.3.4 Duration of drying of farmer-saved rice seeds before storage in the three selected districts of Ashanti Region**

Majority of rice farmers (62 %) dried their seeds for three to five days before storage when there is enough sunshine, while 32and 6 % dried their seeds for seven days and above and two days, respectively (Table 4).

**Table 4: Duration of drying of farmer-saved rice seeds in the three selected districts of Ashanti Region**

| Duration of drying in days | % Rice farmers |
|---|---|
| 2 | 6 |
| 3-5 | 62 |
| 7 and above | 32 |
| Total respondents | 100 |

### 4.1.3.5 Occurrence of pests and diseases of rice seeds in storage observed by rice farmers in the three selected districts

The rice farmers encountered mostly pest problems such as grain weevils and mice in storage (Fig.3). Diseases of rice were not observed, however, 61 % of the farmers had pest problems, whiles, and 39 % of the farmers did not have pest problems (Fig.3). All the farmers stored their seeds under ambient conditions.

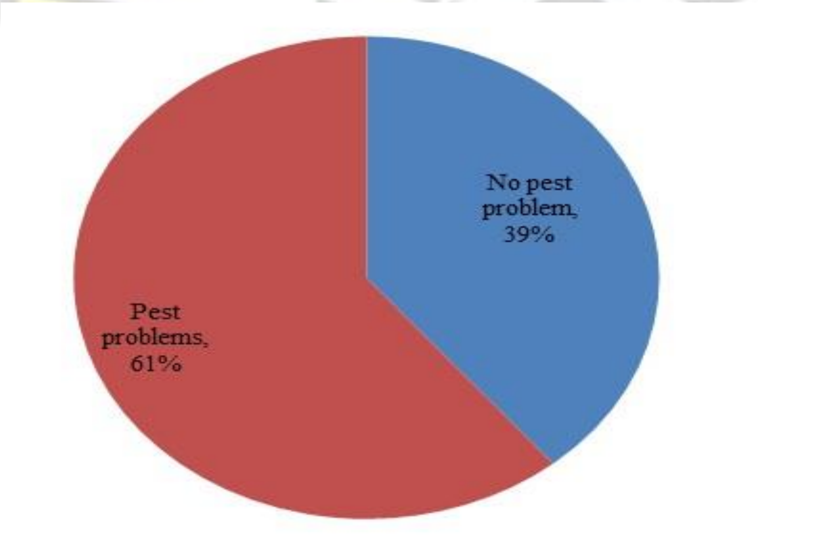


Figure 3: Per cent of farmers in occurrence of pest and diseases in storage

**4.1.[1] Frequency of cropping of rice in a year by farmers in the three selected**

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[1] **.1.4.1 Frequency of cropping and sources of water**

Rice farmers depended on rainfall and irrigation facilities or both as their sources of water for cropping in a year. Most farmers who cropped once in a year depended on rainfall (85 %) as their source of water (Table 6). Rice farmers who cropped twice in a year depended mostly on both irrigation and rainfall (70 %) as their sources of water

**districts**

Rice farmers in the selected districts cropped once to three times in a year. Most farmers (71 %) cropped once in a year, 24 % of farmers cropped twice and 5 % cropped three times in a year (Table 5).

**Table 5: Frequency of cropping of rice per year by farmers in three selected districts of Ashanti Region**

| Frequency of cropping rice/year | % Rice farmers |
|---|---|
| Once | 71 |
| Twice | 24 |
| Thrice | 5 |
| Total respondents | 100 |

**Table 6: Frequency of cropping and sources of water for rice farmers**

| Number of rice cropping/year | % Farmers sources and cropping | | |
|---|---|---|---|
| | Rainfall | Irrigation | Irrigation and rainfall |
| Once | 85 | 10 | 5 |
| Twice | 20 | 10 | 70 |
| Three times | 3 | 87 | 10 |

for cropping. Majority of farmers (87 %) who cropped three times in a growing season depended on irrigation as their source of water.

### 4.1.5 Farmer's knowledge about seed-borne fungal diseases of rice

Most farmers (64 %) did not have knowledge about rice seed-borne fungal diseases, while 30 % of rice farmers had some idea about symptoms of some rice seed-borne diseases and 6 % of farmers were not sure about the diseases (Fig.4).

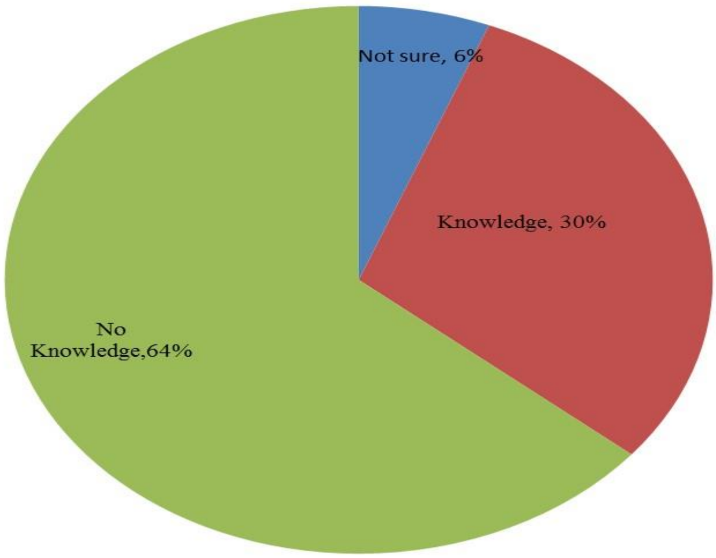


Figure 4: Per cent distribution of farmers' knowledge about seed-borne fungal diseases of rice

## 4.2 Seed health test of sampled farmer-saved rice seeds in the three selected districts

All the samples tested were found to be infected by fungal pathogens but at different levels. The frequency of infection by different fungal pathogens on the collected rice seed samples from the Afigya-Kwabre, Ahafo-Ano and Ejisu-Besease Districts are presented in Tables 7, 8 and 9.A total of 20seed-borne fungi comprising 16 pathogens namely; *Alternaria padwickii, Alternaria* sp., *Bipolaris oryzae, Cercospora*sp., *Colletotrichum* sp.,*Curvularia lunata, Curvularia pallescens, Curvularia* sp., *Fusarium verticillioides, F. oxysporum, F. pallidoroseum, F. solani, Nigrospora oryzae, Phoma* sp., *Sarocladium oryzae, Stemphylium* sp. and four saprophytes namely; *Aspergillus*

*flavus, Aspergillus niger, Penicillium* sp.,and *Rhizopus* sp. were found to be associated with the farmer-saved rice seeds samples collected from the three selected rice growing districts. *Bipolaris oryzae* was the most frequent pathogen present among the 60 rice samples investigated. However, their frequency of infection varied from sample to sample with Ahafo-Ano District showing highest infection of
100% and least infection of 82.6 % for the samples collected from Ejisu-Besease District.

In the Afigya-Kwabre District, *B. oryzae* and *F. verticillioides* recorded highest frequency of infection of 95 % with 19 out of 20 rice samples infected (Table 7). *Cercospora* sp. showed 60 % infection with 12 out of 20 rice samples infected. *Curvularia lunata* had 40 % infection with eight out of 20 rice samples infected. *Fusarium oxysporum* recorded 15 % infection with three out of 20 rice samples infected. However, *F. pallidoroseum* and *Sarocladium oryzae* had the least frequency of infection of 5 % with one out of 20 samples infected (Table 7).
In the Ahafo-Ano South District, *B. oryzae* had the highest frequency of infection of 100 % with all 17 rice samples infected, followed by *F. verticillioides* (88.2 %) with 15 out of 17 rice samples infected. *F. oxysporum* recorded frequency of infection of 76.5 % with 13 out of 17 rice samples infected (Table 8). *C. lunata* recorded frequency of infection of 70.6 % with 12 out 17 samples infected. However, *Cercospora* sp. had 58.8 % infection with 10 out of 17 rice samples infected. Nine out of 17 rice samples collected were infected with *F.pallidoroseum* (52.9 %). Least frequency was recorded by *Alternaria padwiickii*, *Alternaria* sp., *Curvularia* sp., and *Stemphylium* sp. with one out of 17 rice samples infected (Table 8).

In the Ejisu-Besease District, *B.oryzae* had the highest infection of 82.6% with 19 out of 23 rice samples infected, followed by *Cercospora* sp. (60.9 %) with 14 out of 23 rice samples infected. *Fusarium verticillioides* had frequency of infection of 56.5% with 13 out of 23 rice samples infected. Least infection was shown by *F. solani* and *Phoma* sp. (4.4 %) with one out of 23 samples infected (Table 9).

**Table 7: Frequency of infection of rice seed samples by fungi in the Afigya-Kwabre District**

| Fungi recorded | Total rice sample tested | Total rice sample infected | % Infection |
|---|---|---|---|
| *Aspergillus flavus* | 20.0 | 20.0 | 100.0 |
| *Bipolaris oryzae* | 20.0 | 19.0 | 95.0 |
| *Cercospora* sp. | 20.0 | 12.0 | 60.0 |
| *Curvularia lunata* | 20.0 | 8.0 | 40.0 |
| *Fusarium verticillioides* | 20.0 | 19.0 | 95.0 |
| *F. pallidoroseum* | 20.0 | 1.0 | 5.0 |
| *F. oxysporum* | 20.0 | 3.0 | 15.0 |
| *Penicillium*sp. | 20.0 | 10.0 | 50.0 |
| *Phoma* sp. | 20.0 | 2.0 | 10.0 |
| *Rhizopus* sp. | 20.0 | 17.0 | 85.0 |
| *Sarocladium oryzae* | 20.0 | 1.0 | 5.0 |

**Table 8: Frequency of infection of rice seed samples by fungi in the Ahafo-Ano District**

| Fungi recorded | Total rice sample tested | Total rice sample infected | % Infection |
|---|---|---|---|
| *Alternaria padwickii* | 17.0 | 1.0 | 5.9 |
| *Alternaria* sp. | 17.0 | 1.0 | 5.9 |
| *Aspergillus flavus* | 17.0 | 14.0 | 82.4 |
| *A. niger* | 17.0 | 1.0 | 5.9 |
| *Bipolaris oryzae* | 17.0 | 17.0 | 100.0 |
| *Cercospora* sp. | 17.0 | 10.0 | 58.8 |
| *Colletotrichum* sp. | 17.0 | 2.0 | 11.8 |
| *Curvularia lunata* | 17.0 | 12.0 | 70.6 |
| *C. pallescens* | 17.0 | 5.0 | 29.4 |
| *Curvularia* sp. | 17.0 | 1.0 | 5.9 |
| *F. verticillioides* | 17.0 | 15.0 | 88.2 |
| *F. pallidoroseum* | 17.0 | 9.0 | 52.9 |
| *F. oxysporum* | 17.0 | 13.0 | 76.5 |
| *F. solani* | 17.0 | 2.0 | 11.8 |
| *Nigrospora oryzae* | 17.0 | 6.0 | 35.3 |
| *Penicillium* sp. | 17.0 | 5.0 | 29.4 |

| | | | |
|---|---|---|---|
| *Sarocladium oryzae* | 17.0 | 2.0 | 11.8 |
| *Stemphylium* sp. | 17.0 | 1.0 | 5.9 |
| *Rhizopus* sp. | 17.0 | 9.0 | 52.9 |



**Table 9: Frequency of infection of rice seed samples by fungi in the Ejisu-Juaben District**

| Fungi recorded | Total rice sample tested | Total rice sample infected | % Infection |
|---|---|---|---|
| *Alternaria* sp. | 23.0 | 3.0 | 13.0 |
| *Aspergillus flavus* | 23.0 | 22.0 | 95.7 |
| *A. niger* | 23.0 | 3.0 | 13.0 |
| *Bipolaris oryzae* | 23.0 | 19.0 | 82.6 |
| *Cercospora* sp. | 23.0 | 14.0 | 60.9 |
| *Curvularia lunata* | 23.0 | 11.0 | 47.8 |
| *C. pallescens* | 23.0 | 2.0 | 8.7 |
| *Fusarium verticillioides* | 23.0 | 13.0 | 56.5 |
| *F. oxysporum* | 23.0 | 4.0 | 17.4 |
| *F. pallidoroseum* | 23.0 | 9.0 | 39.1 |
| *F. solani* | 23.0 | 1.0 | 4.4 |

**Table**

| | | | |
|---|---|---|---|
| *Penicillium* sp. | 23.0 | 6.0 | 26.1 |
| *Phoma* sp. | 23.0 | 1.0 | 4.35 |
| *Sarocladium oryzae* | 23.0 | 3.0 | 13.0 |
| *Rhizopus* sp. | 23.0 | 23.0 | 100.0 |

### 4.3 Seed treatment effect on fungal pathogens of farmer-saved rice seeds

Four major fungal pathogens were found on the rice seed sample selected for treatment. These were *B.oryzae, Cercospora* sp., *C.lunata* and *F.verticillioides*

#### 4.3.1 Effects of aqueous ginger extract on seed-borne pathogens

Rice seeds treated with ginger extract for 2h resulted insignificant (P<0.05) reduction in incidence of *B.oryzae* (0.7 %), as compared with the untreated seed and seeds treated with Mancozeb for 2 h (Table 11). Seeds treated for 1, 5 and 24h also showed significant (P<0.05) decrease in incidence of *B.oryzae* (1.0, 2.4, and 3.1%, respectively) as compared with untreated seeds. The treatment reduced the incidence of *Cercospora* sp. from 1.2 % in untreated seeds to 0.7 in soaking for 2 h (Table 11). Soaking of seeds for 1 and 2 h however, reduced incidence of *C. lunata* and *F.verticillodes* from 1 and 1.6 % respectively, to 0.7 %.

#### 4.3.2 Effects of aqueous pepper extract on seed-borne pathogens

Treatment of rice seeds with aqueous pepper extract for 24 h showed significant (P< 0.05) reduction in incidence of *B.oryzae* (1.0%) as compared with4.6 % of the untreated seeds but the reduction was similar to that of Mancozeb treatment (Table 13). Seeds treated for 1, 2 and 5h also showed significant decrease in incidence of *B.oryzae* (2.1, 3.1, and 2.9%, respectively) as compared with untreated seeds. However, there was no significant (P>0.05) difference between pepper extract and Mancozeb treatment for 1 h. Seed treatment for 2 h with pepper extract showed significant (P<0.05) reduction in incidence of *Cercospora* sp. And *C. lunata* (0.7 %), as compared with untreated seeds (Table 11). Incidence of *F. verticillioides* was reduced from 2.7 to 1.0 % after treatment for 2 h. However, soaking for 1, 5 and 24 h showed an increase in incidence of *F. verticillioides* with 1.9, 2.4 and 1.6 %, respectively.

### 4.3.3 Effects of aqueous lemongrass extract on seed-borne pathogens

Seed treatment with lemongrass for 24 h resulted in significant ($P<0.05$) reduction in incidence of *B.oryzae* compared with the untreated seed (Table 13). Soaking for 1, 2 and 5 h showed slight reduction in incidence of *B.oryzae* (4.2, 3.8 and 3.9 %, respectively) compared with the untreated seeds. Extract of lemongrass showed significant reduction in incidence of *Cercospora* sp. (0.7 %) after soaking for 1 and 2 h compared with the untreated seed. However, soaking for 5 and 24 h showed no incidence of *Cercospora* sp. Treatment for 2 h resulted in significant ($P<0.05$) reduction in incidence of *C. lunata* compared with the untreated seeds (Table 11). Seed treatment for 1 h showed an increase in incidence of *C. lunata* (2.4 %) compared with 1.2 % in the untreated seeds (Table 10). *F.verticillioides* showed a slight decrease of 1.4 and 1.2 % in incidence after soaking seeds for 2 and 24h compared with 1.6 % in the untreated seeds. However, seed treatment for 1 h resulted in significant ($P<0.05$) increase in incidence of *F.verticillioides* (2.2 %) compared with Mancozeb, and the untreated seeds (Table 10).

### 4.3.4 Effects of Mancozeb on seed-borne pathogens

Seed treatment with Mancozeb showed significant ($P<0.05$) reduction in incidence of all the major pathogens identified at the various soaking periods.

**Table 10: Seed treatment effect on fungi of farmer-saved rice seeds after soaking for 1 h**

| Seed treatments | Incidence of seed-borne fungi | | | | | | |
|---|---|---|---|---|---|---|---|
| | *A. flavus* | *A. niger* | *B. oryzae* | *Cercospora* sp. | *Curvularia lunata* | *F. verticillioides* | *Rhizopus* sp. |
| Ginger | 3.2 | 0.7 | 1.0 | 1.2 | 0.7 | 0.7 | 0.7 |
| Pepper | 8.2 | 8.1 | 2.1 | 0.7 | 1.6 | 1.9 | 4.1 |
| Lemongrass | 5.4 | 0.7 | 4.2 | 0.7 | 2.4 | 2.2 | 1.0 |
| Mancozeb | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 1.6 | 0.7 |
| Sterile distilled Water | 2.2 | 0.7 | 2.5 | 1.4 | 1.2 | 1.0 | 1.2 |
| Lsd(5%) | 0.2 | 0.03 | 0.2 | 0.03 | 0.2 | 0.2 | 0.04 |
| CV (%) | 2.7 | 1.0 | 5.8 | 2.1 | 9.0 | 10.6 | 1.5 |

**Table 11: Seed treatment effect on fungi of farmer-saved rice seeds after soaking for 2h**

| | Incidence of seed-borne fungi | | | | | | |
|---|---|---|---|---|---|---|---|
| Seed treatments | *A. flavus* | *A. niger* | *B. oryzae* | *Cercospora* sp. | *C. lunata* | *F. verticillioides* | *Rhizopus* sp. |
| Ginger | 1.0 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Pepper | 4.8 | 2.4 | 3.1 | 0.7 | 0.7 | 1.0 | 1.9 |
| Lemongrass | 1.0 | 0.7 | 3.8 | 0.7 | 0.7 | 1.4 | 1.0 |
| Mancozeb | 1.0 | 0.7 | 1.0 | 0.7 | 0.7 | 1.0 | 0.7 |
| Sterile distilled Water | 2.3 | 0.7 | 5.0 | 1.2 | 2.4 | 2.7 | 1.2 |
| Lsd(5%) | 0.1 | 0.01 | 0.1 | 0.0 | 0.01 | 0.1 | 0.2 |
| CV (%) | 4.5 | 0.7 | 3.2 | 1.8 | 0.7 | 5.3 | 9.2 |

**Table 12: Seed treatment effect on fungi of farmer-saved rice seeds after soaking for 5h**

| | Incidence of seed-borne fungi | | | | | |
|---|---|---|---|---|---|---|
| Seed treatments | *A. flavus* | *A. niger* | *B. oryzae* | *C .lunata* | *F. verticillioides* | *Rhizopus* sp. |
| Ginger | 1.4 | 0.7 | 2.4 | 0.7 | 1.0 | 0.7 |
| Pepper | 5.0 | 4.1 | 2.9 | 1.0 | 2.4 | 1.0 |
| Lemongrass | 2.4 | 2.9 | 3.9 | 1.0 | 1.7 | 2.5 |
| Mancozeb | 1.0 | 0.7 | 0.7 | 1.0 | 0.7 | 0.7 |
| Sterile distilled Water | 1.0 | 0.7 | 2.8 | 1.2 | 2.6 | 0.7 |
| Lsd (5%) | 0.1 | 0.12 | 0.2 | 0.05 | 0.04 | 0.1 |
| CV (%) | 2.1 | 4.2 | 4.0 | 3.6 | 1.4 | 6.5 |

**Table 13: Seed treatment effect on fungi of farmer-saved rice seeds after soaking for 24h**

| Seed treatments | Incidence of seed-borne fungi | | | | | |
|---|---|---|---|---|---|---|
| | *A. flavus* | *A. niger* | *B. oryzae* | *C. lunata* | *F. verticillioides* | *Rhizopus* sp. |
| Ginger | 1.9 | 0.7 | 3.1 | 0.7 | 1.9 | 0.7 |
| Pepper | 8.5 | 8.8 | 1.0 | 1.2 | 1.6 | 3.9 |
| Lemongrass | 1.2 | 0.7 | 1.7 | 0.7 | 1.2 | 0.7 |
| Mancozeb | 1.0 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Sterile distilled water | 1.9 | 1.0 | 4.6 | 1.7 | 1.9 | 1.0 |
| Lsd (5%) | 0.2 | 0.04 | 0.10 | 0.03 | 0.3 | 0.08 |
| CV (%) | 4.9 | 1.2 | 2.8 | 1.8 | 12.7 | 3.5 |

## 4.4 Seed treatment effect on germination of rice seeds

### 4.4.1 Effects of aqueous ginger extract on germination of rice seeds

Seeds treated with aqueous ginger extract for 24 h showed an increase in germination of 88 %,as compared with the untreated seeds (85 %), but there was significant ($P<0.05$) decrease of 68 and 42 % in germination by seeds treated for 1 and 2 has compared with the untreated (Table 14).

### 4.4.2 Effects of aqueous pepper extract on germination of rice seeds

Aqueous pepper extract treatment for 2 h showed a significant ($P<0.05$) increase in germination (94 %), as compared with Mancozeb (90 %) for 2 h and 72 % in the untreated seeds (Table 14). Seeds treated for 1 h showed an increase in germination to91 %as compared with 82 % in the untreated seeds.

### 4.4.3 Effects of aqueous lemongrass extract on germination of rice seeds

Treatment of seeds with aqueous lemongrass extract for 2 h showed a significant ($P<0.05$) increase in germination (94 %) as compared with Mancozeb (90 %) and the untreated seed (72 %) but was not significantly different ($P>0.05$) from pepper (Table 14). Aqueous lemongrass extract treatment for 1, 5 and 24 h also showed an increase in germination (91, 90 and 86 %, respectively), as compared with the untreated seeds (Table 14).

### 4.4.4 Effects of Mancozeb on germination of rice seeds

Seeds treated with Mancozeb for 24 h showed a significant ($P<0.05$) increase in germination (95 %) as compared with the other treatments and 85 % in the untreated seeds (Table 14). However, treatment for 1 h showed an in increase in germination (87 %) compared with 82 % of the untreated seeds, it was significantly ($P<0.05$) lower as compared with 91 % in ginger and lemongrass aqueous extracts for 1 h.

**Table 14: Seed treatment effect on germination of rice seeds over time**

| | Per cent germination of rice/time (h) | | | |
|---|---|---|---|---|
| Treatments | 1h | 2h | 5h | 24h |
| Ginger | 68 | 42 | 85 | 88 |
| Pepper | 91 | 94 | 84 | 93 |
| Lemongrass | 91 | 94 | 90 | 86 |
| Mancozeb | 87 | 90 | 91 | 95 |
| Sterile distilled water | 82 | 72 | 85 | 85 |
| Lsd (5%) | 1.2 | 1.2 | 1.2 | 1.2 |
| CV (%) | 1.0 | 1.0 | 0.9 | 0.9 |

# CHAPTER FIVE

# DISCUSSION

### 5.1Surveys: Farmers' perception about seed-borne fungal diseases, storage

**containers and practices employed in the storage of farmer-saved rice seeds**

### 5.1.1 Sources of seeds of the smallholder rice farmers in the three selected inland valley rice growing districts of Ashanti Region

Majority of the rice farmers interviewed in this study used their own saved seeds to start their next season planting. This implies that farmer-saved seed may be the main source of seeds for rice farmers in Ashanti Region. This observation agrees with reports by Vo *et al*. (2001) that over70 % of rice farmers depend on their own saved seeds for the next season's planting.

In sub-Saharan Africa, it is established that most farmers do not buy seeds: they save their own or trade with other farmers (Almekinders *et al.*, 1994; Anon, 2001). Farmers depend on their own saved seeds because they do not have access to certified seeds, or when certified seeds are available the prices are too high for the small scale farmer to afford.

### 5.1.2 Farmers' knowledge on rice varieties cultivated

Majority (72 %) of rice farmers in the selected districts knew the name of varieties they cultivated, while 20 % did not have knowledge on their cultivated variety and eight per cent were not sure of the varieties they cultivated. Some of the varieties mentioned were Jasmine 85, Sikamoo, Lapete, Uncle Bens and Vita 7. The most cultivated varieties were Jasmine 85, Lapete and Sikamoo. According to these farmers, Jasmine 85 and Lapete were long grain varieties, early maturing and were resistant to pests and diseases. Jasmine 85 and Lapete also have good aroma and are marketable. Sikamoo, according to these farmers, was a short grain local variety but was resistant to harsh conditions such as drought and flooding but was not as early maturing as Jasmine 85 and Lapete. These findings may, therefore, validate the reason why most smallholder farmers find difficulty in adopting new varieties as was reported by Bull (1989). Lack of knowledge on cultivated varieties by rice farmers may account for seed-borne infections since they do not cultivate disease and pest resistant varieties.

### 5.1.3 Seed storage practices and conditions of rice farmers in the three selected rice growing districts

Most farmers interviewed in the three selected districts stored their seeds in nylon sacks in their homes under ambient conditions. FAO (1981) reported that farmers in the developing world store their produce, including seed, under ambient environment. Chin (1988) also reported that storage under ambient conditions is very practical in the tropical world where relative humidity is low. A good number of containers are used for storing seeds but their suitability depends on the kind or type of seed and the protection the container can offer the seed in storage. However, seed is hygroscopic and would develop equilibrium moisture content with that of the physical environment where it is placed (Copeland and McDonald, 2001). Juliano *et al*. (1990) reported that rice attained equilibrium moisture content with the environment when stored under ambient conditions. However, storage under ambient conditions has been observed to affect seed quality in general and germination in particular. The high incidence of seed-borne fungal pathogens observed on the rice seeds from the three selected districts could be attributed to nylon sacks used by most farmers in storing the rice seeds; the sacks may not have been properly tightened, allowing the seeds to absorb moisture from the environment which facilitated the growth of microorganisms on the seeds.

Seed treatment with chemicals is found to be more useful in storage to maintain better seed quality up to one year by suppressing the storage pests and fungi (Gupta *et al.*, 1989). Seed germination is an essential process in plant development to obtain optimal seedling number for higher seed yield. Advancement in agrotechnical measures embraces the intelligent use of chemical treatment of a crop from the seed stage so as to protect the seed from various microorganisms which cause diseases resulting in low germination with subsequent poor establishment in the field (Alagarsamy and Sivaprakasam, 1988). For some crops, such as maize, groundnut, rice and other cereals, seed treatment is routine and is a necessary and effective means of protecting seeds and seedlings from seed-borne pathogens. Most farmers did not treat their seed before storage and prior to sowing. These farmers were of the view that enough sunshine during drying was enough treatment against pests and diseases. However, few farmers treated their seeds with rodenticides before storage and prior to sowing. Seed treatment with rodenticides may not be enough against seed-borne pathogens. Farmers' seed treatment potential prior to storage and sowing may have accounted for high incidence of storage fungi such as *Aspergillus flavus, A. niger,* and *Rhizopus*. It is important that these farmers are educated to treat their seeds with appropriate fungicides and insecticides before storage. At planting, these farmers must be educated to treat their seeds with appropriate fungicidal products before planting to improve on their plant establishment and yield.

From the survey conducted most farmers interviewed in the three selected districts stored their rice seeds for three to five months. Twenty-seven per cent of farmers stored their seeds for 9-12 months whiles 21 and 14 % of farmers stored their seeds for six to seven and one to two months, respectively. Lack of irrigation facilities and erratic rainfall patterns at their locations, according to the farmers, determined when their stored seeds would be planted. Also, the market price of the rice seeds determined its duration of storage. Seed is stored with the express objective of maintaining quality for both consumption and planting purposes (Agrawal, 1995; George, 1985; FAO, 1981). Chin (1988) proposed that pertinent questions concerning the principal aims of storage and length of storage must diligently be considered before embarking on any seed storage programme. It must, however, be noted that seed deterioration is a natural phenomenon and that the life span of seeds decreases with the passing of time, irrespective of the storage structure used (Harrington, 1972).Moisture content plays an important role in seed storage; seeds can be stored for longer period if these farmers dried their seeds to low moisture content below 13 %. Moisture content of the seeds ranged from 11 to 14 %.  Lovato and Balboni (1997) reported that 13 % is the safe seed moisture content for storage of cereals. The length of the intended storage period is of prime importance as the maximum moisture levels need to be modified for safe storage. The high incidence of seed-borne pathogens in the three selected districts may be attributed to long durations of storage and high moisture content of the seed since these pathogens thrive under high moisture content of seed.

Majority of rice farmers sun-dried their seeds for three to five days before storage when there is enough sunshine while 32 and 6 % dried their seeds for seven days or more, and two days, respectively. Seed drying is necessary to reduce the moisture content of the seed to a safe level for storage. The drying duration and techniques must maintain seed quality by not decreasing the seed's viability. Drying is most critical operation after harvesting. Delays in drying, incomplete drying or ineffective drying will reduce seed quality and viability. Effective storage could also be achieved by these farmers if they dry their seeds properly to low moisture content below 12 %. However, drying seeds even further will slow down physiological aging processes and prolong their useful storage life. High incidence of seed-borne pathogens identified on rice seeds from the three selected districts may be attributed to the short duration of drying thus leading to an increase in moisture content which facilitates fungal growth.

Most farmers encountered pest problems such as grain weevils and mice in storage. Diseases of rice were not observed on rice seeds in storage. Post-harvest loss in rice is around 15 % (Palipane, 2000). Among the many factors that affect in post-harvest losses, insect pest contribute the highest loss is of 5-6 % (Palipane, 2000). Fernando *et al*. (1988) reported that losses in stored rice due to insect pests could go up to 8.8 %. Storage pests such as mice and grain weevils through their feeding habits could cause injuries to the stored rice seeds which could serves as entry points for pathogen infection. The absence of diseases in storage may be attributed to the effective drying of seeds by some farmers and ambient conditions of the stored rice seeds. The high incidence of seed-borne fungi identified from the three districts could also be attributed to activities of storage pests.

### 5.1.4 Frequency of cropping and sources of water to rice farmers in the three selected districts

Rice farmers in the selected districts cropped once to three times in a year. Most farmers (71 %) cropped once in a year, 24 % of farmers cropped twice and 5 % cropped three times in a year. Rice farmers depended on rainfall and irrigation facilities or both as their sources of water for cropping in a year. Most farmers who cropped once in a year depended on rainfall as their source of water. Rice farmers who cropped twice in a year depended most on both irrigation and rainfall (70 %) as their sources of water for cropping. Majority of farmers (87 %) who cropped three times in a growing season depended on irrigation as their source of water. Rice farmers in the selected districts cropped once in a year due to the erratic rainfall patterns, thus making rainfall their main source of water for cropping. Smallholder rice farmers are rural poor folks who do not have enough capital to purchase irrigation facilities.

### 5.1.5 Farmers' knowledge about seed-borne fungal diseases of rice

Most farmers (64%) did not have knowledge about rice seed-borne fungal diseases, while 30 % of rice farmers had some idea about symptoms of some rice seed-borne diseases and 6 % of farmers were not sure about the diseases. From the surveys conducted, farmers do not have knowledge about seed-borne diseases because of their illiteracy rate and they tend to ignore symptoms of the diseases when they appear on their fields and in storage, especially at locations where there are no extension agents to monitor their activities. However, a survey conducted by Asare-Bediako *et al.* (2007) in the northern part of the country reported a high illiteracy rate of 60 % among farmers interviewed. These findings may, therefore, validate the reason why most smallholder farmers rice in the country find difficulty in adopting new farming practices and technologies but rather often use wrong dosages of chemicals, wrong application rates, unimproved seeds as reported by Bull (1989). Lack of knowledge on seed-borne fungal diseases by the smallholder rice farmers may account for the high incidence of seed-borne fungal pathogens identified on the rice seed samples from the three selected districts surveyed.

## 5.2 Seed health status of farmer-saved rice seeds in the three selected districts

On seed health, the present study revealed that none of the seed samples was free from seed-borne pathogenic and saprophytic fungi. The rice seed samples were infected by20 different fungal species, comprising 16 pathogenic and four saprophytic fungi.Seed-borne fungi such as *Alternaria padwickii, Aspergillus niger, A. flavus,*

*Bipolaris oryzae*, *Fusarium verticillioides, F. oxysporum, F. solani* and species of *Phoma*, *Cercospora*, *Penicillium* and *Colletotrichum* have been identified on rice seeds

(Javaid *et al.*, 2002; Wahid *et al*., 2001). *Bipolaris oryzae* was the most important pathogen that was most frequently identified on seeds. This pathogen causes brown spot disease. Gerken *et al*. (2001) reported brown spot disease as one of the serious constraints to rice production in Ghana. Brown spot is one of the important diseases of rice capable of causing losses of 3 – 15 %.Surveys showed that brown spot causes a 5 % yield loss in rice production (Savary *et al*., 2000).Its high incidence in the neighbourhood of 90 – 100 % in the districts is of concern. Pathogen such as *Fusarium verticillioides* can cause Bakanae disease which can be as high as 20 % in epidemic cases. Educating farmers to adopt better seed treatment practices is necessary to sustain yields of farmers. Also, farmers need to be educated to control this disease to avoid the possibility of brown leaf spot outbreak in the three districts. Controlling the pathogenic and saprophytic seed-borne pathogens would go a long way to increase plant establishment during planting and this can contribute to increase in yields.

### 5.3 Effects of seed treatment on fungal pathogens of farmer-saved rice seeds

In experiments to develop appropriate and environmentally friendly ways of controlling seed-borne pathogens, aqueous extract of ginger rhizome was found to be effective in controlling most of the important seed-borne pathogens identified on the rice seeds. The antimicrobial properties of ginger have been widely studied and reported (Hasan *et al.*, 2005).Ginger is known to have analgesic, sedative, cardiotonic and antimicrobial effect (Hibert, 2006).Ginger showed inhibitory effects on *A. niger*, *Rhizopus* and *Penicillium* spp. on seeds of different sunflower cultivars(Afzal *et al*., 2010).

The ability to control seed-borne pathogens was due to the fact that ginger contains 400 different compounds, a mixture of both volatile and non-volatile chemical constituents such zingerone, shogaols and gingerols, sesquiterpenoids (βsesquiphellandrene, bisabolene and farnesene) and a small monoterpenoid fraction (βphelladrene, cineol and citral) (Chrubasik *et al*., 2005; Grzanna *et al*., 2005). These several chemical constituents increase its antimicrobial effectiveness. This antimicrobial activity was believed to be attributed to the major compounds in zingiberene, and their activity could be multiple (Ali *et al.,* 2005; Singh *et al.*, 2008; Anwar *et al.*, 2009).

Various reports are available on the antimicrobial property of the rhizomes of ginger (Habsah *et al.*, 2000; Guptha and Ravishankar, 2005; Nanasembat and Lohasupthawee, 2005) and aqueous extracts from ginger was studied for antimicrobial activity against *Aspergillus niger, Saccharomyces cerevisiae, Trichoderma* sp., *Lactobacillus acidophilus and Bacillus cereus.*

Aqueous extracts of pepper and lemongrass were also effective in controlling seedborne fungi in this study but ginger was the best among them. A number of reports exist that indicate that pepper and lemongrass extracts have antimicrobial properties. Al-Delaimy (1999), reported that the antimicrobial component present in pepper is prescribed for diseases such as diarrhea, and cholera. Pepper has antimicrobial property of actively preventing bacteria such as *E.coli* (Arun, 2001). Pepper extracts have been shown to reduce aflatoxin production in *A. parasiticus* IFO 30179 and *A. flavus* var *columnaris* S46 (Ito *et al*., 1994). Mohamed *et al*. (2006) reported lemongrass extract to be among the most significant of the newly uncovered, nontoxic therapies and one of the most useful antimicrobial agents successfully used for the treatment of all kinds of infections arising from fungi, viruses, bacteria, parasites and other microscopic invaders. Aqueous extracts of lemongrass completely reduced seed infection by *Macrophomina phaseolina*, *F. verticillioides*, *Botryodiplodia theobromae* (Bankole and Adebanjo, 1995).Cold water extract of lemongrass checked the spread of anthracnose of cowpea (Amadioha and Obi, 1999). Somda *et al*. (2007) also found that lemongrass extract reduced *F. verticillioides* infection in sorghum. Lemongrass was also reported to possess antifungal activity capable of controlling postharvest pathogens (Tzortzakis and Economakis, 2007).

### 5.4 Effect of seed treatment on germination of rice seeds

The use of infected seeds without any seed treatment against infecting pathogens is often responsible for the decrease in seedling emergence and germination (Hofs *et al*., 2004). Low seed quality is a serious problem in crop production especially in most developing countries.

Results of this study revealed that all the treatments improved seed germination, except ginger extract. Germination of seeds treated with ginger extracts was lower than the untreated seeds after 1and 2h of seed treatment. The reason may be that the active ingredients in ginger were phytotoxic to the rice seeds. Also, storage fungi (*A. flavus, A. niger* and *Rhizopus* sp.) and pathogenic fungi (*B.oryzae, Cercospora*sp.*, C. unata* and *F. verticillioides*) may have accounted for the reduction in germination by ginger extract. The association of seed-borne pathogens including *C. lunata* and *Fusarium* spp. has been reported on pearl millet cultivars causing reduction in seed germination (Elisabeth *et al*., 2008). Ijaz *et al.* (2001) reported that *Aspergillus niger* is a damaging storage fungus that deteriorates seed quality and reduces seed germination.

The improvement in seed germination by lemongrass and pepper aqueous extracts could be attributed to the suppression of the incidence of the seed-borne fungi. This agrees with that of Parimelazhagan and Francis (1999) who established that leaf extracts of *Clerodendrum viscosum* (Vent.) increased seed germination and improved seedling development of rice seeds. These results strongly suggest seed treatment before planting to escape the infection by seed/soil borne fungal pathogens of seedlings.

## CONCLUSION AND RECOMMENDATIONS

### CONCLUSION

The study revealed that the majority of smallholder rice farmers (71 %) in the EjisuBesease, Ahafo-Ano South and Afigya- Kwabre districts of the Ashanti Region saved their own rice seeds for the next planting season. About 53 % of the farmers used fertilizer nylon bags as storage container and others saved their rice seeds in jute sacks and polythene bags under ambient conditions. Majority of farmers did not treat their seeds before storage and prior to sowing (88 and 94 %, respectively) against insect pests and diseases. Most farmers stored their rice seeds for three to five months. Also, majority of farmers sun-dried their rice seeds for three to five days when there is enough sunshine. Most farmers cropped once in a year and they depended on rainfall as their source of water. Most farmers did not have knowledge about seed-borne diseases of rice. The most prevalent seed-borne fungi of the farmer-saved rice seeds in the three selected districts were*B.oryzae, Cercospora* sp. *C. lunata, F. pallidoroseum, F. oxysporum* and *F. verticillioides* and the saprophytic fungi, *Aspergillus flavus, A. niger, Penicillium* sp. and *Rhizopus* sp.

Aqueous extracts of ginger, lemongrass and pepper were found to be effective in reducing the levels of infection by seed-borne pathogens significantly. Ginger extract was the most effective, and compares favourably with the chemical fungicide (Mancozeb). Aqueous extracts of ginger, pepper and lemongrass could be depended on by smallholder farmers for the management of seed-borne diseases of rice.

## RECOMMENDATIONS

- Farmers should be educated to take proper measures to keep their saved seeds to maintain good health, purity and viability to enhance yield and sustainable rice production.
- Further studies should be conducted to determine the efficacy of these aqueous extracts under field conditions and also search for other plants with better antimicrobial potential and large spectrum of activity.

# REFERENCES

Adegoke, G. O. and Odesola, B. A. (1996). Storage of maize and cowpea and inhibition of microbial agents of biodeterioration powder and essential oil of lemongrass *(Cymbopogon citratus). International Journal of Biodeterioration and Biodegradation*, 62:81-84.

Adityachaudhury, N. (1991). Phytochemicals: their potency as fungicides and insecticides and their prospects of manipulating natural production. In: Biotechnology in Crop Protection. C, Senand S, Dutta (eds.) Kalynana, India: BCKL. Page 4: 314.

Afzal, R., Mughal,S.M, Munir,M., Kishwar,S. Qureshi, R. Arshad, M, and. Laghari, M.K. (2010). Mycoflora associated with seeds of different sunflower cultivars and its management. *Pakistan Journal of Botany*, 42: 435-445.

Agarwal, P.C., Carmen, N. and Mathur, S.B. (1989). Seed-borne diseases and seed health testing of rice. *Technical Bulletin*. Danish Government Institute of Seed Pathology for Developing Countries, Copenhagen, Denmark and CAB International Mycological Institute, Kew, United Kingdom. pp.106.

Agarwal, V.K. (1981). Seed-borne fungi and viruses of some important crops. Walnitali, University Press, Pantangar. 137pp.

Agarwal, V.K. and Sinclair, J.B. (1995). Principles of Seed Pathology. 2nd ed. Boca Raton, FL: CRC Press, Inc. 539 pp.

Agrawal, P. K. (1995). Seed Storage and Packaging Techniques in Seed Science and Technology, 2nd Edition. P. K. Agrawal and M. Dadlani (eds). South Asians Publishers, New Delhi. pp.159- 163.

Alam, S., Akhter, N., Begun,F., Banu,M.S, Islam,M.R, Chowdhary,A.N.and Alam,M.S. (2002). Antifungal activities *in vitro* of some plant extracts and smoke on four fungal pathogens of different hosts. *Pakistan Journal of Biological Science,* 5: 307-309.

Alagarsamy, G. and Sivaprakasam, K. (1988). Effects of antagonists in combination with carbendazim against *Macrophomina phaseolina* infection in cowpea. *Journal of Biological Control,* 2: (2), 123-125.

Al-Delaimy, W. (1999).Microbial diversity.*Fitoterapia*, 6: 147- 162.

Ali, S. M, Khan A. A. Ahmad, I., Musaddiq M., Ahmed, K., Polase, H., Rao, L.V, Habibullah, C.M., Sechi, L.A., and Ahmed, N. (2005). Antimicrobial activities of eugenol and cinnamaldehyde against humangastric pathogen Helicobacter pylori. *Annals of Clinical Microbiology and Antimicrobials*, 4:20.

Aliero A.A., Afolayan A.J. (2006). Antimicrobial activity of *Solanum tomentosum.African Journal of Biotechnology*, 5 (4): 369–372.

Almekinders, C.J. M. Louwaars, N.P. and Bruijn, G.H. (1994).Local seed systems and their importance for an improved seed supply in developing countries.*Euphytica*,78:207-216.

Amadioha, A.C (2000). Control of rice blast *in vitro* and *in vivo* with extracts of *Azadirachta indica.Crop Protection*,19: 287-290.

Amadioha, A.C. and Obi,V.I (1999). Control of anthracnose disease of cowpea by *Cymbopogon citratus and Ocimum gratissimum.Acta Phytopathologica et Entomlogica Hungarica*, 34: 84-89.

Amusa, N.A.,Kehinde I.A. and Adegbite, A.A. (2004). Pepper fruit anthracnose in the humid forest of southwestern Nigeria. *Nutrition and Food Science,* 34 (3):130-134.

Andriesse, W. and Fresio, L.O (1991). A characterization of rice growing environment in West Africa. *Agricultural Ecosystems Environment*, 33: 337395.

Anjorin, S.T. and Mohammed, M. (2009). Effects of Seed-borne fungi on germination and seedling growth of watermelon (*Citrullus lanatus*).*Journal of Agricultural and Social Sciences*. 5: 77–80.

Anonymous. (2005). Pest control background. *International Journal of Pest Control*, 45 (2): 232–233.

Anonymous. (2001). North Dakota organic farmers worry about biotech contamination. *Cropchoice News*, 6 February, 2001.

Anonymous. (2008).Coalition for African Rice Development. Available on line at http//www.jica.go.jp/English/news/field/archieve/2008/pdf/card_e.pdf.Retrieved 26/01/26

Anwar, F., Ali, M., Hussain, A.I and Shahid ,M. (2009). Antioxidant and antimicrobial activities of essential oil and extracts of fennel (*Foeniculum vulgare* Mill.) seeds from Pakistan. *Flavour Fragrance Journal*, 24: 170176.

Arum, S. (2001).Phytochemicals and plant products. *Journal ofPharmacology*,129: 231-234.

Asare-Bediako, E., Showeminio, F. A., Buah, J.N. and Ushawu, Y. (2007). Tomato production constraints at Botanga Irrigation Project in the Northern Region of Ghana. *Journal of Applied Sciences*, 7(3): 459-461.

Badawi, T. A. (2004). Rice-based production systems for food security and poverty alleviation in the Near East and North Africa: New Challenges and Technological Opportunities. FAO, Rome. 56pp.

Bagga, P.S. and Sharma,V.K.(2006). Evaluation of fungicides as seedling treatment for controlling bakanae/foot-rot (*Fusarium verticillioides*) disease in basmati rice.*Journal of Mycology Plant Pathology*, 59: 305–308.

Balandrin, M.F.,Klocke,J.A, Wurtele,E.S. and Bollinger,W.H.(1985). Natural plant chemicals: Sources of industrial and medicinal materials. *Journal ofScience*, 228: 1154- 1160.

Bankole, S.A. and Adebanjo, A. (1995). Inhibition of growth of some plant pathogenic fungi using extracts from some Nigerian plants. *International Journal of Tropical Plant Diseases*, 13: 91-95.

Bankole, S.A. (1996). The distribution and pathogenicity of the seed mycoflora of two tomato varieties cultivated in western Nigeria. *African Crop Science Journal*, (4): 491-496.

Basorun, J. O. (2003). Analysis of the relationships of factors affecting rice consumption in a targeted region in Ekiti-State, Nigeria. *Journal of Applied Quantitative Methods*, 4 (2): 145-153.

Basu, R. N. (1990). Invigoration for extended storability and processing: International Conference on Seed Science and Technology. New Delhi.

Bateman, G.L., Ehle, H. and Wallace,H.A.H. (1986). Fungicidal treatment of cereals seeds. Seed treatment, K.A Jeffs (ed.), British Crop Protection Council Publications, Thornton Heath.pp.83-106.

Berisavljevic, G. K., Blench, R. M. and Chapman, R. (2003). Some features of rice production in Ghana. Available on line at http//www.odi.org/resources/downloaded/3159.pdf. Accessed 09/24/11.

Bewly, J.D. and Black, M. (1994).Seeds: Physiology of Development and Germination.2nd ed. Plenum Press, New York. pp76.

Bilgrami, K.S. and Sinha, K.K. (1983). Aflatoxin contamination in agricultural commodities with special reference to maize and groundnut. *In:* Recent Advances in Plant Pathology,A. Husain,K.Singh,B.P.Singh. and. V.P.Agnihotri, (eds.), Lucknow Print House (India). pp. 253-263.

Boumas, G. (1985). Rice, Grain Handling and Storage. Elsevier Science Publishers B. V. pp. 9-10.

Bull, D. (1989). A Growing Problem: Pesticide and the Third World Poor Farmers. Oxford Press. 207pp.

Buwa, L.V., Staden J.V. (2006). Antibacterial and antifungal activity of traditional medicinal plants used against venereal diseases in South Africa. *Journa. Ethnopharmacology*, 103 (1): 139–142.

Calpe, C. (2003). Status of the world rice market in 2002. *In*: *Proceedings of the 20th Session of the International Rice Commission*, 23–26 July 2002, Bangkok, Thailand. FAO, Rome, Italy. pp. 35–40.

Calpe, C.(2002). Rice in world trade, Part II.Status of the world rice market, *In*:*Proceedings of the 20th Session of the International Rice Commission*, Bangkok, Thailand, 23-26 July 2002. Pp225.

Cantliffe, J. D. (1998).Seed Germination for Transplants. *Horticultural Technology*, 8 (4). Florida Agricultural Experiment Station Journal Series N-01421

Catal`a, M. (1995). Chemical and cultural practices for red rice control in rice fields in Ebro Delta, Spain. *Crop Protection*, 5:405–408.

Chandler, J. (2005). Cost reduction in School for International Training programmes using exosect auto-dissemination as part of area wide integrated pest management. *International Journal of Pest Control*, 42 (2): 257–260.

Charjan, S.K.U. (1995). Studies on antifungal activity of some medicinal plant product on Jowar grains during storage.*In* : *Proceedings of the 82nd Science Congress Part-III*. Kolkata, India, 1995.

Chaudhary, R.C and Dat van, T. (1999). Can Africa be the future Rice bowl for Asia? *In:Proceedings of the 4th Asian International Rice Conference*. Cebu, the Philippines. 29pp.

Chin H.F (1988).Storage and Testing of Forage seeds in the Tropics. www.fao.org. AG/AGP.doc.PUBLC. grasslan/151.pdf. Retrieved 23/05/11.

Christensen, C.M. and Kaufmann,H.H. (1965). Deterioration of stored grains by fungi. *Annual Review Phytopathology*,3**:** 69-84.

Christensen, C.M. and Kaufmann,H.H. (1979). Grain storage: The role of fungi in quality loss. Minneapolis: University of Minnesota Press. 153 pp.

Christensen, J.J. (1963). Longevity of fungi in barley kernels. *Plant Disease. Reporter,* 47**:** 639-642.

Chrubasik, S., Pittler,M.H. and Roufogalis,B.D. (2005). Zingiberis rhizome: Comprehensive review on the ginger effect and efficacy profiles. *Phytomedicine*, 12: 684-701.

Clerk, G. C. (1974). Crops and their diseases in Ghana. Ghana Publishing Corporation, Tema. 144pp.

Clottey, V.A., Karbo,N. and Gyasi,K.O. (2009). The tomato industry in northern Ghana: Production constraints and strategies to improve competitiveness. *African Journal of Food & Agriculture, Nutrition and Development,* 9(6): 5-9. Copeland, L. O. and McDonald, B. M. (2001). Principles of Seed Science and Technology.Technology and Engineering.4th Ed. Chapman and Hall, New York. Pp. 201- 214.

Cromwell, E., Wiggins, S. and Wentzel, S. (1993).Sowing Beyond the State: NGOs and Seed Supply in Developing Countries.Overseas Development Institute, London, UK. 98pp.

De Matouschek, A. (1991). Phytochemical studies on non-volatile constituents of *Cymbopogon citratus* (DC.) Stapf. grown in Morocco. *Pharmaceutica ActaHelvetiae*. 66:242-245.

De Waard, S.K.,Georgopoulos,S.G., Hollomon,D., Ishii,H., Leroux, P., Ragsdale, N. N. and Schwinn, F. J. (1993). Chemical control of plant diseases: Problems and prospects. *Annual Review of Phytopathology*, 31: 403-421.

Defoer, T., Wopereis, M.C, Jones, M.P., Lançon, F. and Erenstein,O. (2003). Challenges, Innovations and Changes towards rice-based food security in SubSaharan Africa. Pp. 219-234. *In*: *Proceedings of 20th Session of the International Rice Commission*. Bangkok, Thailand.23-26 July 2002. Rome Italy: FAO.

Dharam, V. (1986). Storage diseases of wheat. *In:* Problems and Progress of wheat Pathology in South Asia. L.M. Joshi, D.V. Singhand K.D. Srivastava (eds.). Malhotra Publishing House, New Delhi. pp. 296-304.

Dharam, V. (1974). Study of some problems associated with postharvest fungal spoilage of seeds and grains. *In:* Current Trends in Plant Pathology, S.P. Raychaudhury and J.P. Verma (eds.), Lucknow: Botany Department, Lucknow University. pp. 221-226.

Dharam, V.,Mathur,S.B and Neergaard,P. (1971). Efficacy of certain fungicides against seed-borne infection of stackburn disease of rice caused by *Trichoconis padwickii.IndianPhytopathology*, 24: 343-346.

Doijoe, S.D. (1988). Changes in seed quality on deterioration in tomato. *Progressive Horticulture*, 20 (3-4): 253-256.

Dubey, R.C., Kumar, H.and Pandey, P.R. (2009). Fungi toxic effect of neem extracts on growth and sclerotial survival of *Macrophomina phaseolina in vitro*. *Journal of Animal Science*, 5: 17-24.

Ebuehi, O.A.T. and Oyewole, A.C. (2007). Effect of cooking and soaking on physical characteristics, nutrient composition and sensory evaluation of indigenous and foreign rice varieties in Nigeria. *African Journal of Biotechnology*,6 (8):10161020.

Elias, S., Garay, A., Hanning, S. and Schweitzer, L. (2004). Testing the quality of seeds in cereals.Oregon State University Seed Laboratory, USA.

Elisabeth, Z.P., Paco, S., Vibeke, L., Phillipe, S.,Irenee, S. and Adama, N. (2008). Importance of seed-borne fungi of sorghum and pearl millet in Burkina Faso and their control using plant extracts. *Pakistan Journal of Biological Sciences,* 11(3):321-331.

Epners, Z. (1964). A new psychrophilic fungus causing germination failure of conifer seeds.*Canadian Journal of Botany*, 42: 1,589–1,604.

Ergene, A., Guler, P., Tan S., Mirici S., Hamzaoglu E. and Duran, A. (2006). Antibacterial and antifungal activity of *Heracleum sphondylium* subsp. *artvinense*.*African Journal Biotechnol*ogy, 5 (11): 1087–1089.

Fageria, N. K., Slaton, N.A. and Baliges,V.C. (2003). Nutrient management for improving lowland rice productivity and sustainability. *Advances in Agron*omy, 80: 63-152.

Fakir, G.A., Hossain, I., Ahmed, M.U., Asad-ud-Doullah, M. and Alam, S (2002).Quality of farmers Boro and T. Aman rice seeds collected before sowing from Bogra, Rajshahi and Rangpur districts of Bangladesh. *A paper presented in the review and planning meeting of the Rice Seed Health Improvement (SHIP), PETRRA project held* at BRRI, Gazipur, Bangladesh. 2002.

FAO (1981). Cereal and grain-legume seed processing. *Technical Guidelines.*No.21 W. P. Freistritzer, J. H .Vock, A. F. Kelly and E.K. Ziger (eds.). Rome. Pp. 3, 33-43, 51-53.

FAO. (2005). Food and Agricultural Organization Statistics Book on National Crop Production. Rome, Italy. pp. 89.

Fernando, M.D., Palipane, D. K., and Adhikaranaike, T. B. (1988). Improvement of farm level grain storage methods in Sri-Lanka. *Tropical Post Harvest Technologist.* 1(1): 47-67.

Ferrero, A. (2003). Weedy rice, biological features and control. In: R. Labrada (ed.) Weed management for developing countries. Addendum 1. FAO Plant Production and Protection Paper, Rome, Italy. pp. 89–109.

Fomba, S.N. and Taylor, D.R.(1994). Rice blast in West Africa: it nature and control. *In*: R.S, Zeigler, S.A Leong and P.S. Teng, (eds.). Rice Blast Disease. CAB International, Wallingford, UK, in association with IRRI, Manila, Philippines.

Fungi in rice seeds (*Oryza sativa* L.). *Summa Phytopathologica.* 27(4): 403-409.

Genstat. (2007). Lawes Agricultural Trust (Rothamsted Experimental Station). Genstat Release 9.2.

George, T. A. R. (1985).Vegetable Seed Production.Longman Group Limited, London and New York. pp. 64-98.

Gerken, A., Suglo, J. V.and Braun, M. (2001). Crop Protection Policy in Ghana: An economic analysis of current practice and factors influencing pesticide use. PPRSD/GTZ, MOFA, Accra, 185 pp.

Gottlieb, O.R.,Borin,M.R. and Brito,N.R. (2002). Integration of ethnobotany and phytochemistry: Dream or reality? *Phytochemistry*, 60(2): 145–152.

Govindarajan, V.S. (1982). Ginger: Chemistry, technology and quality evaluation (part1). *Critical Review of Food Science Nutrition,*17(1*):*1-96.

Grzanna, R., Lindmark,L. and Frondoza,C.G. (2005). Ginger and herbal medicinal product with broad anti-inflammatory actions. *Journal of Medicinal Food,* 8: 125-132.

Gupta, P.C, and O'Toole, J.C. (1986). Upland rice: A global perspective. International Rice Research Institute, Los Baños, Philippines.360 pp.

Gupta, R.P., Ushamehra, Pandey, U.B. and Mehra, U. (1989). Effect of various chemicals on viability of onion seed in storage. *Seed Research,* 17 (1): 99-101.

Guptha, S. and Ravishankar, S. (2005). A comparison of the antimicrobial activity of garlic, ginger, carrot and turmeric pastes against *E.coli* in laboratory buffer and ground beef. *Foodborne Pathogens and Diseases.* 2(4):330_340.

Habsah, M., Amran, M., Mackeen, M.M., Lajis, N.H., Kikuzaki, H., Nakatani, N., Rahman, A.A. and Ghafar Ali, A.M. (2000). Screening of Zingiberaceae extracts for antimicrobial and antioxidant activities. *Journal of Ethnopharmacology*,72 (3):403_410.

Haque, A.H., Akon, M.A.H., Islam, M.A., Khalequzzaman, K.M. and Ali, M.A. (2007). Study of seed health, germination and seedling vigour of farmers produced rice seeds. *International Journal of Sustainable Crop Production,* 2(5): 34-39.

Harborne, J.B. (1998). *Phytochemical methods*: A guide to modern techniques of plant analysis. 3rd ed. Chapman & Hall Pub., London, UK. pp.7–8.

Harman, G.E. and Pfleger, F.L. (1974). Pathogenicity and infection sites *of Aspergillus* in stored seeds.*Phytopathology,* 64: 1339-1344.

Harrington, J.F. (1972). Seed storage and longevity, *In*: I.T, Kozlowski. (ed.), Seed Biology, Academic Press, New York and London.3: 145-245.

Harris, C.A., Renfrew,M.J. and Woolridge, M.W. (2001). Assessing the risk of pesticide residues to consumers: Recent and future developments. *Food Additives and Contaminants*, 18(12): 1124–1129.

Hasan, M.M., Chowdhry, S.P., Alam, S., Hossain B. and Alam, M.S. (2005). Antifungal effects of plant extracts on seed-borne fungi of wheat seed regarding seed germination,seedling health and vigour index. *Pakistan Journal of Biological Science*, 8: 1284-1289.

Hemanth, M., Rah, M.,Niranjana,S.R., Chandra, N. S.and Shetty,H. S. (2007). Health status of farmer's saved paddy, sorghum, sunflower and cowpea seeds in Karnataka, India.*World Journal of Agricultural Sciences*, 3 (2): 167-177.

Hibert, S. (2006). Medicinal properties of ginger.http://www.jamaica-gleaner.com /gleaner/20061012/eyes/eyes1.html.

Hofs, A., Schuch,L. O. B., Peske, S.T, and Barros, A.C.S.A. (2004). Emergence and initial growth of rice seedlings according to seed vigour. *Revista Brasileira de Sementes*. 26(1): 92 – 97.

Hong, T.D. and Ellis, R. H. (1996). Desiccation Tolerance and Potential Longevity of developing seeds of rice (*Oryza sativa*).*Annals ofBotany*, 73: 501-506.

Huynh, V. N, Pham, V.D. and Mathur,S.B. (2001). Effect of cleaning on seed health and seed germination of rice. *OMonRice*, 9: 138-139.

Ijaz, A.,Anwar, S. A., Riaz, A. and Khan, M. S. A. (2001). Seed-borne pathogens associated with wheat and their role in poor germination. *Pakistan Journal of Phytopathology*, 13:102-106.

ISTA. (1985). Internationation Rules for Seed Testing.Seed Science and Technology, 24, Supplements Rules.

Ito, H., Chen, H. and Bunnak, J. (1994). Aflatoxin production by microorganisms of the *Aspergillus flavus*group in spices and the effect of irradiation. *Journal of Science Food Agriculture*, 65: 141-142.

Javaid, M. S., Wahid,A., Idrees, M., Gill, M. A. and Saleem, A. (2002). Seed mycoflora studiesin rice. *Pakistan Journal of Phytopathology*, 14: 132-134.

Juliano, O. B., Perez, M. C., and Chang, T. T. (1990).Varietal differences in longevity of tropical rough rice stored under ambient conditions. Seed Science and Technology. *Proceedings of the International Seed Testing Association.*18 (2): 361-369.

Kagale, S., Marimuthu, T.,Thayumanavan, B., Nandakumar, R and Samiyappan, R. (2004). Antimicrobial activity and induction of systemic resistance in rice by leaf extract of *Datura metel* against *Rhizoctina solani* and *Xanthomonas oryzae*pv. *oryzae.Physiological and Molecular Plant Pathology*, 65, 91-100.

Kannaiyan, S.and Prasad, N.N. (1981). Effect of organic amendments on seedling infection of rice caused by *Rhizoctonia solan, Plant Soil*, 62:131-133.

Kasumov, F. Y. and Babaev, R. I. (1983). Components of the essential oil of *Cymbopogon citratus*. *Chemistry of Natural Compounds*, 19(1); 108, DOI: 10.1007/BF00579986. http://www.springerlink.com/content/x26784424g80l7 35/ [Accessed on: 28th April 2010].

Kavitha, R., Umesha, S. and Shetty, H.S. (2005). Dose dependent impact of dominant seed-borne fungi on seed germination and seedling vigour of cotton seeds. *Seed Science Research*, 33 (2): 187–194.

Khan, M.W., Khan, A.M. and Saxena, S.K. (1974). Rhizospheric fungi and nematodes of eggplant as influenced by oil cake amendments. *Indian Phytopathology*, 27: 480-484.

Kormawa, P.M., Keya, S.  andTouré, A.A. (2004). Rice research and production in Africa. Rice Outlook 2004. Marseille, France, 29-30 June, 2004.

Kulik, M.M. (1973). Susceptibility of stored vegetable seeds to rapid invasion by *Aspergillus amstelodami* and *Aspergillus flavus* and effects on germinability. *Seed Science and Technology*, 1:779-803.

Kuhn, P.J., and Hargreaves, J.A. (1997). Anti-fungal substance from herbaceous plant, *In*: F.G. Pegg and A.G. Ayres (eds.), Fungal infection of plants. *Symposium of the British Mycology* Society. Cambridge University Press. pp 48-179.

Kumar, K., J. Singh and Ratan, V. (2004).Seed-borne fungi of cowpea, their parasitisms and control.*Annuals Plant Protection Science*, 12:80-82.

Lanteri, S. and Quagliotti, L. (1997). Problems related to seed production in the African region. *Euphytica*,96: 173-183.

Leong, S.A. (2004). What major problem or issue is being resolved and how are you resolving it (summarize project aims and objectives)? How serious is the problem? What does it matter? Presentation at the Beaumont Texas A&M Research and Extension Center, July 8, 2004.In: http://www.ars.usda.gov /research/projects/projects

Linares, O. F. (2002). African rice (*Oryza glaberrima*) history and future potential. *Proceeding of the National Academy of America*; *National Academy of Sciences*; Vol. 99, No. 25, pp. 16360-16365.

Linscombe, L. S, (2006). Rice cultivar designated cheniere; Available at http//www.freepatentsonline.com/741725.htm. Accessed 03/03/10.

Livestrong.com, (2010). Lemongrass nutrients. http://www.livestrong.com/article/ 338483-lemongrass-nutrients/ [Accessed on: 15th September 2010].

Lovalto, A. and Balboni, N. (1997). Seed vigor in maize (*Zea mays.* L.): Two-year laboratory and field test compared.*Indian Journal of Agronomy*. 1: 1-6

Mafongoya, P.L., Bationo, A., Kihara, J. and Waswa, B.S. (2006). Appropriate technologies to replenish soil fertility in southern Africa. *Nutrient Cycling Agroecosystem*, 76: 137-151. doi: 10.1007/s10705006-9049-3.

Marthur, S. B. and Kongsdal, O. (2003). Common laboratory seed health testing methods for detecting fungi published by the International Seed Testing Association (ISTA).Bassersdorf, CH., Switzerland. pp.89.

.Marthur, S.B. and Neergaard, P (1970). Seed-borne fungi of rice in Phillipines, India, Portugal and Egypt:Investigation on *Trichoconis padwikii*. *Proceedings of First International Symposium on Plant Pathology*. New Dehli.pp.69-81.

Masuda, T., Odaka, Y., Ogawa, N., Nakamoto, K. and Kuninaga, H. (2008). Identification of geranic acid, a tyrosinase inhibitor in lemongrass (*Cymbopogon citratus)*. *Journal of Agric Food Chemistry*, 56(2):597-601

Maurice, M.I. (1993). *Handbook of African Medicinal plants*. Nsukha, Nigeria. pp. 225-265.

Meena, M.R. (1992). *Studies on* anti-microbial activity of various spices and their oils. M.Sc. Thesis. Indian Agricultural Research Institute, New Delhi.

Mehrotra, B.S. (1983). The impact of fungal infestation of cereal grains in field and storage. *In:* Recent Advances in Plant Pathology, A. Husain, K. Singh, B.P. Singh and V.P. Agnihotri (eds.), Lucknow Print House (India). pp.185-200.

Mehrotra, B.S. and Agarwal,A.(2003). *Plant Pathology*, 2nd edition, Teta Mc Grawhill Publishing Company New Delhi, India, pp. 254.

Mew, T.W. and Gonzales, P.(2002). A Handbook of rice Seed-borne fungi. SciencePublishers, Inc, 83pp.

Mew, T.W., Misra, J.K. and Merca, S.D. (1994). A Manual of Rice Seed Health Testing, International Rice Research Institute, IRRI, pp3.

Miller, J.D. (1995). Fungi and mycotoxins in grain implications for stored product research. *Journal of Stored Product Research*, 31 (1): 1–16.

MOFA. (2009). Agriculture in Ghana: Facts and Figures. Statistics, Research and Information Directorate (SRID), Ministry of Food and Agriculture, Accra.

MOFA/IVRDP, CSIR/CRI and CSIR/SARI. (2005). Rice Production Guide, Ghana

MOFA-SRID. (2007), Statistical Research information Department under Ministry of Food and Agriculture.

Mohamed, I.A.I, Bauiomy, M.A.M. and Ibrahim, A.S.A. (2006). Efficacy of different natural products as safe management of guar damping-off disease in Egypt. *Egyptian Journal. Phytopathology*, 34: 1-15.

Mohana, D.C., Raveesha, K.A. and Lokanath, R. (2008). Herbal remedies for the management of seed-borne fungal pathogens by an edible plant *Decalepis hamiltonii* (Wight & Arn). *Archives of Phytopathology and Plant Protection*, 41 (1): 38–49.

Mohana, D.C., Pravin, P., Veena, V. and Raveesha, K.A. (2011). Plant extracts effect on seed-borne pathogenic fungi from seeds of paddy grown in southern India. *Journal of plant Protection Research,* 51(2): 101-106.

Nanasembat, S. and Lohasupthawee, R. (2005). Antibacterial activity of crude ethanolic extracts and essential oils of spices against *Salmonella* and other enterobacteria. King Mongkut's Institute of Technology*Science Technolgy Journal*, 5(3):527-538.

Nanir, S. P. and Kadu, B.B. (1987). Effect of medicinal plant extracts on some fungi, Acta Botanica. India 15: 170.

Nguefack, J., Somda, I., Mortenseen, C.N. and Amvam Zollo, P.H. (2005). Evaluation of five essential oils from aromatic plants of Cameroon for controlling seedborne bacteria of rice (*Oryza sativa*L).*Seed Science and Technology*, 33: 397407.

Nsemwa, L.T.H. andWolffhchel,H.(1999). Occurrence of seed-borne fungal pathogens in rice seeds from the southern highlands of Tanzania. *African Crop Science Journal*, 7: 217-222.

Nutsugah, S. K. (1997a). Survey of rice diseases/pests in Northern Ghana. *In*: *Proceedings of the 6thAnnual WARDA IPM.TF Meetings*, March 2-5, 1997. Bouaké, Côte d.Ivoire.

Nutsugah, S. K. (1997b). Survey of diseases/pests of upland/hydromorphic rice in Northern Ghana.*Proceedings of the SARI Annual In-house Review*, March 2426, 1997, Nyankpala, Ghana.

Nutsugah, S. K. and Twumasi J. K. (2001). Fungal Diseases of rice in Ghana: Knowledge and research needs. *In*: S. Sreenivasaprasad and R. Johnson, (eds.). Major fungal diseases of rice recent advances. Kluwer Academic Publishers. The Netherlands, pp. 321-329.

Nwanza, K.F. (1996).WARDA.RT5-4P2Indd/www.irri.org/publication/today/pdfs/5-4/16-17pdf. Date accessed 10/02/2011.

Oduro, K. A. (2000). Checklist of Plant Pests in Ghana.Vol. 1. Diseases.Ministry of Food and Agriculture. 105 pp.

Ogbo, E.M and Oyibo, A.E. (2008). Effects of three plant extracts (*Ocimumgratissimum*, *Acalypha wilkesiana* and *Acalypha macrostachya*) on post-harvest pathogen of *Persea americana.Journal of Medicinal Plants Research*, 2:311-314.

Olakojo, A. S., Ayanwole, A. J. and Obasemola, I. V. (2007). Laboratory Screening of some cowpea cultivars (*Vigna unguiculata*) for tolerance humid Environment. *American-Eurasian Journal of Agricultural and Environmental Science*,2 (5): 528-533.

Otoo, E. (1994). Towards increased rice production in Ghana: Research on the sustainable development of the inland valleys for rice production. *Paper presented at the International Seminar*, *Towards Rice Self-Sufficiency in Ghana*, 6-7 June 1994, Akosombo, Ghana.

Ou, S.H.(1985). Rice diseases. CAB International Mycological Institute, Kew, Surrey, U.K. 395 pp.

Ou, S.H. (1985). Rice diseases.Second Edition. CAB. International, Farnham House, Farnham Royal, Slough. 380 pp.

Palipane, K. B. (2000). Milling and quality improvement in rice. *Rice Symposium*, December 14-15, 2000, Ganorrrura, Sri-Lanka.

Pamplona-Roger, G.D. (2007). Healthy Foods, Editorial Safeliz, Spain.3 75 pp.

Parekh, J., Karathia, N. and Chanda, S. (2006). Evaluation of antibacterial activity and phytochemical analysis of *Bauhinia variegata* L. bark. *African Journal Biomedical Research*, 9: 53–56.

Parimelazhagan, T. and Francis, K. (1999).Antifungal activity of *Clerodendrum viscosum* against *Curvularia lunata* in rice seeds. *Journal of Mycology and PlantPathology*,*29* (1): 139-141.

Public Agenda. (2009). Controversy over Ghana's Rice Import Bill. March 2nd, 2009. ISSN 0855-2061.

Pulver, E.L. and Nguyen, V.N. (1999). Sustainable rice production issues for the third millennium. *In*: *Proceedings of the 19th session of the international rice commission* held from 7–9 September1998 in Cairo, Egypt. pp 32–44.

Rhodes, E.R. (1995). Nutrient depletion by food crops in Ghana and soil organic nitrogen management. *Agricultural Systems*, 48: 101-118. DOI:10.1016/0308521X(95)93648-W.

Rosegrant, M.W., Cai,X., Cline, S. and Nakagawa, N.(2002). The role of rainfed agriculture in the future of global food production.Environment and Production Technology Division, International Food Policy Research Institute, Washington, DC.20006, USA.

Savary, S., Willocquet, L., Elazegui, F.A, Teng, P.S., Du, P.V., Zhu, D., Tang, Q., Huang, S., Lin, X., Singh, H.M. and Srivastava, R.K. (2000). Rice pest constraints in tropical Asia: Characterization of injury profiles in relation to production situations. *Plant Disease*, 84:341-356.

Singh, D. (1990). Health of seeds and grains produced in the tribals of Bajasthan in India. *Seed Pathology News* No.20.GGISD, Denmark.pp.3.

Singh, D. and Maheshwari,V.K. (2001). The influence of stackburn disease of Paddy on seed health status. *Seed Research*, 29: 205-209.

Singh, R.S. (1986). Incidence of black scurf on potatoes in oil cakes amended soil. *Indian Phytopathology*, 35: 300-305.

Singh, V.P. and Singh, R.K. (2000). Rainfed rice: A sourcebook of best practices and strategies in eastern India. International Rice Research Institute, Los Baños, Philippines. 292 p.

Singh, G., Kapoor, I.S, Singh, P., Heluani ,C.S., Lampasona, M.P. and Catalan, C.A.N. (2008). Chemistry, antioxidant and antimicrobial investigation on essential oil and oleoresine of Zingiber officinale. *Food Chemistry Toxicology*, 46: 3295-3302.

Solh, M. (2005). Rice is life in 2004 and beyond. International Rice commission *Newsletter*54:1-10

Somda, I., Leth, V. and Sereme, P. (2007). Evaluation of Lemongrass, Eucalyptus and Neem aqueous extracts for controlling seed-borne fungi of sorghum grown in Burkina Faso. *World Journal of Agricultural Sciences*, 3(2): 218-223, 2007.

Somado, E.A., Guei, R.G., and Keya,S. O.(2008). "*NERICA: The New Rice for Africa Compendium*". Available at http//www.warda.org/publications/nericacomp/Nerica%20Compedium.pdf. Accessed 18/07/09.

Stoorvogel, J.J., Smaling E.M.A, Janssen, B.H. (1993). Calculating soil nutrient balances in Africa at different scales. *Fertilizer Research*, 35:227-235. DOI: 10.1007/BF00750641

Suhaila, M., Sizama, S., El Sharkawy,S.H. Ali, A. M and Sepial, M. (1996). Antimycotic screening of 58 Malaysian plants against plant pathogens. *PesticidesScience* 43(3): 259-264.

Takoradi, A. A. (2008). Ghana needs 700,000 metric tonnes of rice annually but currently produces only 150,000. Available at http//www.modernghana.com/news/185343/1/ghana-needs-700000-tonnes-ofrice-annually-but-cur.htm. Accessed 12/09/09.

Than, P., Prihastuti, H., Phoulivong, S., Paul, W., Taylor, J. and Hyde, K.D. (2008). Chilli anthracnose disease caused by *Colletotrichum* species. *International symposium on fungal diversity*, October 16-19, 2008, Hangzhou, China.

Tomlins, K., Manful, J., Larweh, P. and Hammond, L. (2005). Urban consumer preference and sensory evaluation of locally produced and imported ice in West Africa. *Food Quality and Preference*, 16: 79-89.

Torres, R. (1993). Citral from *Cymbopogon citratus* (DC) Stapf (lemongrass) oil. *Philippines Journal of Science*, 122:269-287.

Traore, k. (2005). Characterization of novel rice germplasm from West Africa and genetic marker associations with rice cooking quality. Doctoral dissertation, Texas A&M University. Texas A&M University. Available electronically from http://hdl.handle.net/1969.1/4146.

Tripathi, P and Dubey, N.K. (2004). Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of fruits and vegetables. *Post Harvest Biology and technology*, 32: 235-245.

Tuite, J.F. (1961). Low incidence of storage moulds in freshly harvested seed of soft red winter wheat. *Plant Disease Reporter*,43**:** 470.

Twumasi, J. K. (1996). Survey on rice diseases in Southern Ghana. *Proceedings of the Annual WARDA IPM Task Force Meeting.* March 20-22, 1996. Bouaké, Côte d.Ivoire.

Twumasi, J. K. (1998). *Country Report from Ghana in Workshop on Rice Crop Protection in Africa.*December 8-10, 1998, NRI, Chatham Maritime, Kent, UK.

Twumasi, J. K. and Adu-Tutu, K. O. (1995).Weeds and fungal diseases of rice in selected inland valleys in Ghana. *Proceedings of the Annual WARDA IPM Task Force Meeting*, March 15-17, 1995. Monrovia, Liberia.

Tzortzakis, N. G. and Economakis, C. D. (2007). Antifungal activity of lemongrass (*Cympopogon citratus* L.) essential oil against key postharvest pathogens.*Innovative Food Science and Emerging Technologies.* 8(2): 253-258.

University of Greenwich (1999). Grain Storage Management PG Dip/MSc Computer Mediated Distance Learning Course 1.Storage and Handling- Volume 2.University of Greenwich, Central Avenue, Chatham Maritime, Kent, Me4 4TB, UK. pp. 134- 162.

Valencia, J. and Myers, C. (1998). Lemongrass, *Citronella* grass. Specialty and minor crops handbook.ANR Publications, University of California, Davis, California. pp 80-81.

Varma, J. and. Dubey,N.K.(1999). Prospectives of botanical and microbial products as pesticides of tomorrow. *Current Science*, 76 (2): 172–179.

Virmani, S.S. (1979). Breeding rice foriron toxicity.*In WARDA Proceedings of the Second Varietal Improvement Seminar*, Monrovia, Liberia, September, 14-18, 1979.

Vo, V.A., Ho, V.C., Le, Q.C. and Le, V.H. (2001). Farmers' perception on rice seed management of some provinces in Southern Vietnam. P*roceeding of Workshop on rice seed health for disease management.* Plant protection department IRRI. pp. 1-14.

Walker, D. J., Tripp, R., Apau, A., Dankyi, A. A. and Delimini, L. L. (1997). Seed management by small-scale farmers in Ghana. A study of maize and cowpea seed in Brong Ahafo and Volta Regions. NRI Bulletin in since 1997.

Wahid, A., Javaid, M. S.,Idrees, M. and Gill,M. A. (2001). Studies on the association and effect of *Fusarium solani* on rice seeds in Punjab, Pakistan. In: *Proceedings of 3rd National Conference. of Plant Pathology*, October, 1-3, 2001. NARC, Islamabad, Pakistan. pp. 70-72.

WARDA. (2005). Rice trends in Sub-Saharan Africa, Third Edition, Cotonou, 2005. pp. 31 and FAO Stat; IRRI, Rice Almanac, 3rd Edition, Los Banos, 2002. pp.79

WARDA. (1993). The Consultative Group on International Agricultural Research.Technical Advisory Committee, 16th Meeting, 20 March-3 April, 1993.Rome,

Webster, R.K. and Gunnell, P.S. (1992).Compendium of rice diseases.American Phytopathological Society, St. Paul, Minnesota.62 pp.

Xian-Xiang, J. (1990). Rice Production 1. China International Centre for Agricultural. Training, South China Agricultural University, Guangzhou, China. pp. 13-32.

Zadoks, J.C. (2002). Fifty years of crop protection, 1950-2000. *Netherland Journal of Agricultural Science,* 2002:181-193.

## APPENDICES

**Appendix 1: Occurrence of fungi recorded on 17 rice seed samples collected from Ahafo-Ano South District**

| Fungi isolated | Number of seeds infected | Frequency of occurrence (%) |
|---|---|---|
| *Alternaria padwickii* | 170.0 | 5.0 |
| *Alternaria* sp. | 34.0 | 1.0 |
| *Aspergillus flavus* | 2057.0 | 60.5 |
| *Aspergillus niger* | 68.0 | 2.0 |
| *Bipolaris oryzae* | 3400.0 | 100.0 |
| *Cercospora* sp. | 680.0 | 20.0 |
| *Colletotrichum* sp. | 34.0 | 1.0 |

| | | |
|---|---|---|
| *Curvularia lunata* | 731.0 | 21.5 |
| *Curvularia pallescens* | 119.0 | 3.5 |
| *Curvularia* sp. | 17.0 | 0.5 |
| *Fusarium verticillioides* | 2669.0 | 78.5 |
| *F.pallidoroseum* | 561.0 | 16.5 |
| *F.oxysporum* | 714.0 | 21.0 |
| *F.solani* | 34.0 | 1.0 |
| *Nigrospora oryzae* | 221.0 | 6.5 |
| *Penicillium* sp. | 68.0 | 2.0 |
| *Sarocladium oryzae* | 68.0 | 2.0 |
| *Stemphylium* sp. | 68.0 | 2.0 |
| *Rhizopus* sp. | 1666.0 | 49.0 |

Total rice seeds tested = 3400

**Appendix 2: Occurrence of fungi recorded on 23 ricesamples collected from Ejisu-Besease District**

| Fungi isolated | Number of seeds infected | Frequency of occurrence (%) |
|---|---|---|
| *Alternaria* sp. | 138.0 | 3.0 |
| *Aspergillus flavus* | 4600.0 | 100.0 |
| *Aspergillus niger* | 161.0 | 3.5 |
| *Bipolaris oryzae* | 4508.0 | 98.0 |
| *Cercospora* sp. | 1380.0 | 30.0 |
| *Curvularia lunata* | 1794.0 | 39.0 |
| *C. pallescens* | 23.0 | 0.5 |
| *F.verticillioides* | 874.0 | 19.0 |
| *F.oxysporum* | 92.0 | 2.0 |
| *F.pallidoroseum* | 552.0 | 12.0 |
| *F.solani* | 23.0 | 0.5 |
| *Penicillium* sp | 276.0 | 6.0 |

| | | |
|---|---|---|
| *Phoma* sp. | 92.0 | 2.0 |
| *Sarocladium oryzae* | 69.0 | 1.5 |
| *Rhizopus* sp. | 4600.0 | 100.0 |

Total rice seed tested = 4600

**Appendix 3: Occurrence of fungi recorded on 20 rice samples collected from Afigya-Kwabre District**

| Fungi isolated | Number of seeds infected | Frequency of occurrence (%) |
|---|---|---|
| *Aspergillus flavus* | 4000.0 | 100.0 |
| *Bipolaris oryzae* | 3800.0 | 95.0 |
| *Cercospora* sp. | 760.0 | 19.0 |
| *Curvularia lunata* | 280.0 | 7.0 |
| *Fusarium verticillioides* | 2420.0 | 60.5 |
| *F.pallidoroseum* | 60.0 | 1.5 |
| *F.oxysporum* | 180.0 | 4.5 |
| *Penicillium* sp. | 1440.0 | 36.0 |
| *Phoma* sp. | 40.0 | 1.0 |
| *Rhizopus* sp. | 3600.0 | 90.0 |
| *Sarocladium oryzae* | 49.0 | 1.0 |

Total rice seed tested= 4000

**Appendix 4: Effect of seed treatment after 1 h of exposure on test fungi**

| | % Occurrence of test fungi/treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatments | *A. flavus* | *A. niger* | *B. oryzae* | *Cercospora* sp. | *C. lunata* | *F. verticillioides* | *Rhizopus* sp. |
| Ginger | 1.5 | 0.0 | 0.5 | 1.0 | 0.0 | 0.0 | 0.0 |
| Pepper | 25.0 | 65.5 | 4.0 | 0.0 | 2.0 | 3.0 | 16.5 |
| Lemongrass | 5.5 | 0.0 | 17.0 | 0.0 | 5.5 | 4.5 | 0.5 |
| Mancozeb | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sterile distilled water | 0.5 | 0.0 | 6.0 | 1.5 | 1.0 | 0.5 | 1.0 |

Values have not been transformed

**Appendix 5: Effect of seed treatment after 2 h of exposure on test fungi**

| Treatments | % Occurrence of test fungi/treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| | *A. flavus* | *A. niger* | *B. oryzae* | *Cercospora* sp. | *C. lunata* | *F. verticillioides* | *Rhizopus* sp. |
| Ginger | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pepper | 23 | 0.5 | 9.0 | 0.0 | 0.0 | 0.5 | 3.0 |
| Lemongrass | 0.5 | 5.5 | 14.0 | 0.0 | 0.0 | 1.5 | 0.5 |
| Mancozeb | 0.5 | 0.0 | 0.5 | 0.0 | 0.0 | 0.5 | 0.0 |
| Sterile distilled water | 5.0 | 0.0 | 25.0 | 1.0 | 5.5 | 7.0 | 1.0 |

Values have not been transformed

**Appendix 6: Effect of seed treatment after 5h of exposure on test fungi**

| Treatments | % Occurrence of test fungi/treatment | | | | | |
|---|---|---|---|---|---|---|
| | *A. flavus* | *A. niger* | *B. oryzae* | *C. lunata* | *F. verticillioides* | *Rhizopus* sp. |
| Ginger | 1.5 | 0.0 | 5.5 | 0.0 | 0.5 | 0.0 |
| Pepper | 25.0 | 16.5 | 8.0 | 0.5 | 5.5 | 0.5 |
| Lemongrass | 5.5 | 8.0 | 14.5 | 0.5 | 2.5 | 6.0 |
| Mancozeb | 0.5 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 |
| Sterile distilled water | 0.5 | 0.0 | 7.5 | 1.0 | 6.5 | 0.0 |

Values have not been transformed

**Appendix 7: Effect of seed treatment after 24 h of exposure on test fungi**

| Treatments | % Occurrence of test fungi/treatment |
|---|---|

| | *A. flavus* | *A. niger* | *B. oryzae* | *C. lunata* | *F. verticillioides* | *Rhizopus* sp. |
|---|---|---|---|---|---|---|
| Ginger | 3.0 | 0.0 | 9.0 | 0.0 | 3.0 | 0.0 |
| Pepper | 72.5 | 77.5 | 0.5 | 1.0 | 2.0 | 15.0 |
| Lemongrass | 1.0 | 0.0 | 2.5 | 0.0 | 1.0 | 0.0 |
| Mancozeb | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Sterile distilled water | 3.0 | 0.5 | 20.5 | 2.5 | 3.0 | 0.5 |

Values have not been transformed

**QUESTIONNAIRE** on seed-borne fungi of farmer-saved rice seeds in inland valleys in three selected districts of Ashanti Region.

1. Name of farmer…………….
2. Sex….
3. Age….
4. Level of education of farmer
5. How long have you been in rice production?
6. How long have you been cultivating rice on your land?
7. Do you cultivate rice on the same piece of land every year?
8. What type of cropping systems do you practice? Do you intercrop?
9. What are the major constraints encountered in your rice production?
10. Of these constraints which is most important?
11. What are the main pests encountered in your rice production?
12. What are the main diseases encountered in your rice production?
13. At what stage of production do you see these problems? Seeds, seedlings, etc
14. Is there a need for pest and disease control? Yes / No
15. What are the symptoms of the diseases?
16. How do you manage or control these pests and diseases?

17. Do these pests and diseases reduce your yield?

18. Can these pests and diseases be managed to produce appreciable yields?

19. How do you select your varieties?

20. Where do you obtain your rice seeds?

21. What varieties do you use and why?

22. Do you plant under irrigation?

23. How many times in the year do you plant rice?
24. What month do you plant your rice and why?

25. How do you know rice is matured?

26. How do you harvest your rice?

27. How do you store your harvested rice?

28. Do you treat your seeds before storage? How?

29. What chemical do you use in treating your rice seeds before storage?

30. Are pests and diseases encountered in storage?

31. What are the symptoms observed on the rice seeds during storage?

32. How long do you store your rice seeds?

33. Do you treat your seeds before sowing?

PLATES FROM RESEARCH


Setup for identification of seed-borne pathogens


Rice seeds plated in petri dishes before incubation

Plant material and aqueous extracts preparation

Plating of rice seeds before incubation

Rice field infected with Brown spot


A section of rice farmers interviewed during survey