KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

TITLE OF THESIS:

Effect of farmer seed management practices on the quality of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L. (Walp)) seeds from five ecological zones of Ghana

A THESIS SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES IN PARTIAL FULFILMENT OF THE MSc. SEED SCIENCE AND TECHNOLOGY AT THE DEPARTMENT OF HORTICULTURE OF THE FACULTY OF AGRICULTURE, COLLEGE OF AGRICULTURE AND NATURAL RESOURCES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

PRESENTED BY

DAVID TEYE SACKEY

June, 2010.

DECLARATION

I hereby declare that this work being submitted as a thesis is the result of my own original research and that it has neither in whole nor in part been presented for another degree elsewhere and that reproduction of this thesis in part or in full is strictly reserved unless authorised by the author and the parties associated with this work, herewith under a written agreement.

.... Date..

David Teye Sackey

(Student)

.... Date..

Dr (Mrs) N. S. Olympio

(Supervisor)

.... Date..

Dr J. N. L. Lamptey

(Co-Supervisor)

.... Date..

Mr P. Y. Adjei

(Head of Department)

ABSTRACT

A field research to assess seed management practices of farmers and quality of seed maize and cowpea used by farmers in crop cultivation in the five ecological zones of Ghana was conducted from September 2009 to January 2010. All the five ecological zones of Ghana were sampled for seed maize while four ecological zones were sampled for cowpea seeds.

A total of 90 maize and 29 cowpea seed samples were collected for the study. Formal questionnaires were administered to 119 farmer respondents concerning their seed management practices.

The use of farmer-saved seed maize and cowpea seed in Ghana was predominantly common across all the five ecological zones of Ghana sampled with a minimum of 23% in the Coastal Savannah zone and a maximum of 67% in the Transition zone. Their method of seed storage was found to be 60% of farmers using store rooms and only 10% stored their seed in the cold room across all the agro-ecological zones. However, 60% of the farmers across the agro-ecological zone treated their seeds with insecticide before storage with 83% in the Transition zone, and 80% of the farmer across the agro-ecological stored their seed for a maximum duration of six month.

With the method of seed processing 100% and 51% of the farmers across the agroecological zones used manual method for cowpea and maize respectively. The use shelling machine for maize was 83% in the Transition zone the highest among the five agro-ecological zones.

Seed purity percentages were extremely high across all the five ecological zones of Ghana with a minimum of 96.6% in the Coastal Savannah zone and a maximum of 99.4% in the Forest zone.

The widespread incidence of *Fusarium monoliforme* (37.1-49.4%), *Botryodiplodia theobromae* (1.8-10.3%), *Acremonium strictum* (0.6-5.6%), *Fusarium pallidoroseum* (0.03-0.07%) and *Bipolaris maydis* (0.06-0.14%) were encountered in maize samples across all the ecological zones of Ghana.

The seed health test of cowpea sampled in four ecological zones also revealed the presence of four major seed-borne fungi namely *Fusarium oxysporum*, (14.3-49.7%),

Fusarium pallidoroseum (4.5%), *Macrophomina phaseolina* (0.6%) and *Colletotrichum lindemuthianum* (0.06%).

The Forest zone recorded all the five seed-borne fungal pathogens isolated in the seed health analysis of seed maize samples. *Fusarium monoliforme, Botryodiplodia theobromae* and *Acremonium strictum* were detected in the maize samples from all the five ecological zones of Ghana.

Fusarium oxysporum was also identified in cowpea samples from all the four ecological zones of Ghana.

ACKNOWLEDGEMENTS

With profound gratitude and thanks, I acknowledge the able supervision and invaluable guidance given me by my supervisors, Dr (Mrs) N. S. Olympio of the Department of Horticulture, KNUST, Kumasi and Dr J. N. L. Lamptey of the Crops Research Institute of CSIR, Fumasua. They ceaselessly saw me through all areas of the field and laboratory works, which led to success of this research. A lot of thanks also go to Dr R. A. Asuboah of Grains and Legumes Development Board and his able technician Madam Favour for their logistical and technical support during the laboratory work.

I must thank my Head of Department, Mr P. Y. Adjei for pushing this thesis through. Many thanks are also due to the entire team of lecturers of the Department of Horticulture whose constructive criticism during seminar presentations finally straightened up the research. Also, I thank Alliance for a Green Revolution in Africa (AGRA-EACI) for granting me the scholarship for the MSc Programme.

Many thanks also go for the MoFA district directors and their extension staff across the country who unreservedly assisted me in the field survey by identifying critical locations and respondents for data and sample collections.

I am grateful to Mr Samuel Nyarkoh and Madam Zipporah and their team of technicians especially sister Rose, Maa Comfort, and Maa Esther at the Seed Pathology laboratory of Crops Research Institute, Fumesua for their enormous assistance during the laboratory analysis. I am grateful to Dr Moses of CRI, Fumesua, for his advice and encouragement during the laboratory work.

To my dear and loving wife, Gertrude and sweet daughter Nana who supported me financially, spiritually and materially, I say a 'big thank you' to you. To my dear mother, Mum Felicia and sister-in-law, Gifty and to other members of the Sackey and Quaye families, I say I am ever grateful for your love, care and hearty support given me and still doing in my life and career. Finally, I thank all the brethren in Christ and friends for their spiritual and moral support.

The Lord God Almighty whom I dedicate this thesis to, bless you all.

Table of Contents

List of tables

List of figures

List of plates

List of appendices

List of acronyms

Fm	*Fusarium moniliforme*
Bt	*Botryodiplodia theobromae*
Acs	*Acremonium strictum*
Fp	*Fusarium pallidoroseum*
Bm	*Bipolaris maydis*
Fo	*Fusarium oxysporium*
Mp	*Macrophomina phaseolina*
Cl	*Colletotrichum lindemuthianum*
MC	Moisture content
GGDP	Ghana Grains Development Project
SSA	Sub-Saharan Africa
MoFA	Ministry of Food and Agriculture
CSIR	Centre for Scientific and Industrial Research
CRI	Crops Research Institute
WHO	World Health Organization

1.0. Introduction

Quality characteristics of seed intended for planting include germination, vigour, freedom from weed seeds, genetic purity, and the level of seed-borne infection. Planting seed that is free of seed-borne pathogens is the primary means of limiting the introduction of pathogens, especially new pathogens, into a field. Planting infected seed may also result in widespread distribution of disease within the crop, and could allow for an increased number of initial infection sites early from which the disease can spread (Wright and Tyler, 1994).

The consequences of planting infected seed depend on the pathogen in question. For those diseases that are primarily soil or residue-borne, planting infected seed is less important. The greatest concern is for those diseases where the pathogen is not commonly established in all soils, such as *Fusarium graminearum* the causal organism of stalk rot of maize (Wright and Tyler, 1994). Micro-organisms may develop on seeds in field crops before harvest. Colonisation of the developing seeds depends on the climatic conditions, the presence of an inoculum source and the susceptibility of the crop. Fungi that establish on the developing seed in the field may be broadly of two kinds, saprophytic field fungi and pathogenic fungi (Wright *et al.*, 1995). There is awareness that the increasing movement of seed germplasm around the world also provides an avenue for the dispersion of crop pathogens (Hampton and Tekrony, 1995).

The potential benefits from the distribution and use of good quality seed of improved varieties are enormous, and the availability of quality seed of a wide range of varieties of crops to farmers is key to achieving food security in Ghana. Enhanced productivity, higher harvest index, reduced risks from pest and disease pressure, and higher incomes are some of the direct benefits potentially accruing to farmers (Wright and Tyler, 1994). Faced with different choices of high quality seeds, farmers would select varieties suitable to their local environmental and socio-economic conditions. Furthermore, increases in production through the use of improved varieties in a given area can create employment opportunities related to processing, marketing, and other activities generated through quality seed production (Wright *et al*., 1995).

Seed-borne pathogenic fungi may survive for long periods in storage and may attack seedlings during germination leading to poor emergence and a reduced seedling population. Pathogens may also be transmitted from the seed to the seedling causing disease symptoms and possible yield loss at a later stage of growth. Some seed borne diseases can multiply rapidly from one generation to the next and seed crops can also become infected from neighbouring diseased crops. In this way seed-borne disease can seriously affect the quality of both certified and farmer-saved seed (Wright *et al.*, 1995).

Seed-borne pathogens may result in loss in germination, discolouration and shrivelling. Other results may be development of plant diseases, distribution of pathogen to new areas, introduction of new strains or physiologic races of the pathogen along with new germplasm from other countries and toxin production in infected seed (Nutsuga *et al.*, 2004).

The seed health test results of a study by Nutsugah *et al.* (2004) in Ghana identified important seed-borne pathogens in the seed samples tested that relate to quality seed production. Even though there is lack of evidence of outbreak of seed-borne disease in Ghana, control of seed-borne pathogens is the first step in any agricultural crop production and protection programme. The objectives were;

1. to determine the farmer seed management practices of maize and cowpea in the different agro-ecological zones of Ghana

2. to identify the major seed-borne fungal pathogens of maize and cowpea in the agro-ecological zones of Ghana
3. to determine the levels of seed-borne pathogens in the different agro-ecological zones of Ghana.

2.0. Literature Review

2.1. Fungal Diseases of Maize

There are many causes of low maize yield of which diseases play a significant role. Moreover seed-borne diseases cause enormous losses both in storage as well as in the field. A total of 112 diseases are known to occur on maize (USDA, 1960) of which 70 are seed-borne. Important seed-borne diseases of maize are leaf spot, leaf blight, collar rot, kernel rot, stalk rot, ear rot, scutellum rot, seedling blight, anthracnose and head smut (Richardson, 1990).

2.1.1. Kernel rot and black bundle disease

The disease is caused by *Acremonium strictum* (Mathur and Kongsdal, 2003). The pathogen survives in the soil, plant debris and seed. The disease is favoured by post flowering water stress. The disease kills the plant prematurely after flowering. Infected plants do not show symptoms until they reach the tasseling stage (CIMMYT, 2004). Wilting generally starts from the top leaves. Leaves become dull green, eventually loose colour and become dry (CIMMYT, 2004). In advanced stages the stalk loses its healthy green colour, lower portions become dry, shrunken with or without wrinklings, hardens and turns purple to dark brown which is more prominent on lower internodes. When split open, diseased stalks show brown vascular bundles starting in the underground portion of the roots. Diseased plants produce only ears with undeveloped shrunken kernels. In severe cases affected plants remain abortive causing 100 per cent loss (CIMMYT, 2004).

2.1.2. Southern leaf blight

This disease is caused by *Bipolaris maydis* (Mathur and Kongsdal, 2003). Leaves show greyish, tan, and parallel straight sided or diamond shaped 1-4 cm long lesions with buff or brown borders or with prominent colour banding or irregular zonation (Ullstrup, 1985). Symptoms may be confined to leaves or may develop on sheaths, stalks, husks, ears and cobs. The lesions are longitudinally elongated typically limited to a single inter vascular region, often coalescing to form more extensive dead portions (Ullstrup, 1985). Young lesions are small and diamond shaped. As they mature, they elongate. Growth is limited by adjacent veins, so final lesion shape is rectangular and 2 to 3cm long (CIMMYT, 2004). Lesions may coalesce, producing a complete burning of large areas of the leaves. Southern maize leaf blight is prevalent in hot, humid, maize growing areas. The fungus requires slightly higher temperatures for infection (CIMMYT, 2004).

2.1.3. Black kernel rot

The causal pathogen of this disease is *Botryodiplodia theobromae* (Mathur and Kongsdal, 2003). The same fungus can produce stalk rot with a conspicuous black discoloration in moist, hot environments (CIMMYT, 2004). Affected ears develop deep black, shiny kernels and husk leaves can also turn black and be shredded (CIMMYT, 2004). It develops in hot, humid environments. Diseased plants dry prematurely. Splitting stalks show some shredding of the pith and a dark gray to black discoloration of the vascular bundles (CIMMYT, 2004). Abundant greyish mycelia are conspicuous in the rotten areas, confined mostly to the lower internodes above ground (CIMMYT, 2004). Unlike charcoal rot, *Botryodiplodia* stalk rot does not produce black pinhead-like sclerotia in the rotten areas, but it does produce abundant, gray-blackish, cottony mycelium in cavities formed in the pith of affected internodes. (CIMMYT, 2004).

2.1.4. Ear rot, stalk rot, root rot and kernel rot

This disease is caused by the fungus *Fusarium moniliforme* (Mathur and Kongsdal, 2003). This species and other *Fusarium* species also cause ear, kernel and root rot and seedling blight (Mathur and Kongsdal, 2003). Corn and sorghum are the most economically important hosts of *Fusarium moniliforme* (Partridge, 2008). It is important to note that the fungus has a very broad host range influencing crop production in many areas of the world. Stalk rot is generally thought of as a problem of senescing plants (Partridge, 2008). A higher incidence of stalk rot is common when conditions that tend to encourage early senescence occur. Two such conditions are water stress and foliar diseases. Insect or hail injury may also result in more stalk rot as will high plant populations and imbalanced fertility (high N to K ratio) (Partridge, 2008). The infection process occurs when the fungus invades host tissue directly or through wounds. Mycelium and conidia serve as primary inoculum. Common points of entry are roots and stalks at the base of leaf sheaths. Weather conditions that favour stalk rot development are dry weather before silking and warm wet weather after silking (Partridge, 2008).

The earliest symptoms of stalk rot are wilted plants in the field (Partridge, 2008). Infected plants take on a greyish green hue then turn tan (Partridge, 2008). Outward symptoms of the disease are indefinite discoloured patches on the lower internodes (Partridge, 2008). The pith disintegrates, leaving vascular strands intact. Stalks feel spongy when squeezed. A pink growth is evident on vascular strands when spores are produced. There is also a reddish-pink discoloration of the roots (Partridge, 2008). These symptoms are best observed by splitting stalks longitudinally. As with many stalk rots, lodging is another common symptom (Partridge, 2008).

2.2. Fungal diseases of cowpea

Cowpeas are susceptible to a wide range of pests and pathogens that attack the crop at all stages of growth (Allen, 1983). Some 40 species of fungi are cowpea pathogens (Allen, 1983). Among these are Fusarium wilt, Alternaria leaf spot, Anthracnose, Ascochyta blight, Ashy stem blight, Brown blotch, Cercospora leaf spot, Dampingoff of seedlings, Septoria leaf spot, and Web blight (Allen, 1983).

2.2.1. Fusarium wilt

Fusarium wilt is caused by *Fusarium oxysporum* (Mathur and Kongsdal, 2003). Symptoms include stunting of the affected cowpea plant, chlorosis, drooping, premature defoliation, withering of leaves and brownish purple discoloration of vascular tissues (Boyhan *et al.*, 1999). The leaves become flaccid and chlorotic, and young plants show fairly rapid wilting leading to death. Transmission occurs through soil and seed (Singh *et al.,* 1997).

The disease can be prevented by using resistant cowpea varieties (Singh and Rachie, 1985). Root knot nematodes provide conducive conditions for the pathogen to infect the plant therefore their control will help in reducing the rate of infection by *Fusarium* (Davis *et al.*, 1991).

2.2.2. *Alternaria* leaf spot

Alternaria cassiae Juriar & Khan has been identified as the causal organism of a new disease of cowpea (La Grange and Aveling, 1998). It has been observed in Botswana and the Mpumalanga and Gauteng provinces of South Africa.

Foliar symptoms begin as semi-circular water-soaked lesions at the leaf edges (La Grange and Aveling, 1998). Lesions enlarge towards the centre of the leaf, becoming necrotic (La Grange and Aveling, 1998). Sporulation is visible with the naked eye on the leaf surface as black velvet mass. Occasionally circular lesions are also observed in the centre of the leaf (La Grange and Aveling, 1998). Lesions begin as small brown to reddish brown spots, surrounded by a yellow halo. Lesions enlarge and become water-soaked, and black masses of conidia are visible on the brown necrotic tissue surface (La Grange and Aveling, 1998).

The pathogen is seed-borne and can possibly also overwinter as mycelium in infected plant debris. Spores are produced abundantly on infected plants, especially during frequent rains and heavy dews. The disease is most severe during warm conditions with rain (La Grange and Aveling, 1998).

Alternaria diseases are primarily controlled through the use of resistant varieties, disease-free or treated seed and through the use of chemical sprays such as maneb, mancozeb, chlorothalonil, captofol and fentin hydroxide (Agrios, 1988).

2.2.3. Anthracnose

Until recently a form of *Colletotrichum lindemuthianum* [Sacc. and Magn.] Briosi and Cav. was regarded as the cowpea anthracnose pathogen. However, on the basis of various molecular, morphological and antigenic differences that exist between the anthracnose pathogens of cowpea and *Phaseolus* spp., it has been suggested that the cowpea anthracnose pathogen is probably a form of *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. (Emechebe and Florini, 1997). The pathogen is widely distributed especially in bean-production areas and can cause serious losses in monocropped cowpeas (Singh & Allen, 1979) and where conditions are wet and humid for the main part of the growing season (Latunde-Dada, 1990). *Colletotrichum dematium* (Pers.) Grove has also been found to cause anthracnose in South Africa (Smith and Aveling, 1997).

Anthracnose in cowpeas affects all above ground parts, especially the stem (Singh &

Allen, 1979). Symptoms are typically tan to brown, sunken to lenticular lesions which rapidly spread on susceptible varieties to girdle stems, peduncles and petioles (Onesirosan and Barker, 1971; Singh & Allen, 1979; Emechebe and Florini, 1997). Such girdled stems may turn black (Onesirosan and Barker, 1971). Sporulation on susceptible varieties is profuse, but does not occur on resistant varieties, on which lesions appear as shiny, reddish brown or tiny, necrotic flecks (Emechebe and Florini, 1997).

Although cowpea varieties resistant to anthracnose are available, the pathogen is highly variable and some varieties are putative (Emechebe and Florini, 1997). The pathogen is seed-transmitted in cowpea (Emechebe and McDonald, 1979). The use of seed obtained from anthracnose-free multiplication fields is usually combined with the growing of resistant varieties to control the disease (Emechebe and Florini, 1997). Some foliar fungicides such as benomyl and carbendazim have reduced losses due to anthracnose, but strains of the fungus resistant to many of the effective fungicides have been detected (Emechebe and Florini, 1997).

2.2.4. Ashy stem blight

Macrophomina phaseolina (Tassi) Goid. causes an economically important disease of cowpeas and beans, known as ashy stem blight or charcoal rot (Schwartz, 1989; De Mooy and Burke, 1990; Hagedorn, 1991).

According to Schwartz (1989) and Hagedorn (1991) the first symptom on beans is a small irregularly shaped, sunken, black canker on seedling stems. This canker spreads upward, enlarges and girdles the stem, eventually killing the plant. The cankers have definite black margins and may contain concentric rings. Infection of older plants may cause stunting, chlorosis and premature defoliation leading to death of the plant. These symptoms are often more pronounced on one side of the plant.

Numerous small, black sclerotia or pycnidia form on mature, ashy-grey cankers. Pods and seeds may also show lesions (Hagedorn, 1991).

There is a lack of information on the control of ashy stem blight, especially in cowpea. General control measures include correct planting dates, crop rotation, seed treatments and the use of resistant varieties (Holliday, 1980).

2.2.5. Brown blotch

Brown blotch of cowpea is caused by *Colletotrichum capsici* (H. Syd.) E. Butl. & Bisby and *Colletotrichum truncatum* (Schwein.) Andrus & Moore. (Emechebe and Florini, 1997).

Diseased plants show purplish-brown discolouration of petioles, leaf veins, stems, peduncles and pods. Other symptoms include failure of seeds to germinate, seedling damping-off, flowers aborting and immature pods mummifying. Symptoms first appear either at the stem base or characteristically on pedicles following flowering. Discolouration may be accompanied by cracking of stems (Singh and Allen, 1979). Measures used in the control of anthracnose also apply to brown blotch. As both pathogens are seed-borne in cowpea (Emechebe and McDonald, 1979), the use of seed treatments such as benomyl or carbendazim is a viable control option. Foliar applied fungicidal sprays are effective under field conditions but may not be economically feasible for the small-scale farmer (Emechebe and Florini, 1997).

2.2.6. Cercospora leaf spot

Cercospora canescens and *Cercospora cruenta* both cause Cercospora leaf spot on cowpeas (Williams, 1975). Both pathogens are widespread in warmer regions, occurring on various legumes. They can cause considerable leaf spotting of cowpea after flowering (Singh and Allen, 1979). *C. canescens* produces circular to irregular cherry-red to reddish brown lesions, up to 10 mm in diameter (Singh and Allen, 1979).

When there are numerous lesions, the leaves turn yellow and abscise (Williams, 1975). On the abaxial leaf surfaces the lesions are also coloured red.

The pathogens are seed-borne in cowpea (Williams, 1975). Conidia are easily detached and blown long distances by the wind (Agrios, 1988). Sources of primary infection are infected seeds, alternate hosts and infected debris (Singh & Allen, 1979). Both species appear to sporulate on pods, especially during wet weather. According to Agrios (1988), the fungus favours high temperatures and therefore it is more destructive in the summer months and in warmer climates. Although *Cercospora* spores need water to germinate and penetrate, heavy dews seem to be sufficient for abundant infection (Agrios, 1988).

These two species of *Cercospora* can be completely controlled with foliar applications of the systemic fungicide, benomyl (Williams, 1975). Agrios (1988) suggested spraying the plants, both in the seedbed and in the field, with fungicides such as benomyl, dyrene, chlorothalonil, Bordeaux mixture, maneb and dodine. The use of clean seed or seed at least three years old and resistant varieties may also be used as control measures (Agrios, 1988; Singh and Allen, 1979).

2.2.7. Septoria leaf spot

Septoria leaf spot caused by *Septoria vignae* P. Henn. and *Septoria vignicola* Rao, is important in the savannahs of Africa (Singh and Allen, 1979). According to Williams (1975) it is only occasionally seen in wetter forest regions and is more important in the savannah region of Nigeria. In northern Nigeria *S. vignae* causes serious diseases of cowpea (Emechebe and McDonald, 1979). Rawal and Sohi (1984) found that *S. vignicola* causes severe defoliation leading to yield loss of up to 40%.

Leaf lesions caused by *Septoria* sp. are characterised by bright red to dark red roughly circular to irregular spots, 2-4 mm in diameter, appearing similar on the upper and lower leaf surfaces (Williams, 1975). Spots are often concentric ringed, and sometimes raised, giving the leaf a freckled appearance. Heavily spotted leaves turn yellow and abscise (Williams, 1975; Singh and Allen, 1979).

Septoria sp. is a soil inhabitant in most tropical agricultural soils. This seed-borne pathogenic fungus is transmitted from seed to seedling (Emechebe and McDonald, 1979). Splashing rain, irrigation tools, water, animals, etc spreads the conidia. *Septoria* sp. overwinters as mycelium and as conidia within pycnidia on and in infected seed or on diseased plant debris left in the field (Agrios, 1988). The fungus requires high moisture for infection and severe disease development, but it is able to cause diseases at a wide range of temperatures between 10 and 27°C (Agrios, 1988). Limited information is available on the control of *Septoria* leaf spot on cowpea, but according to Anilkumar *et al*. (1994) the use of chemical control is unlikely to be considered because cowpea is generally grown as a rainfed crop on marginal lands or as a mixed crop with millet, therefore, use of resistant cultivars become imperative. The control of *Septoria* diseases in general depends on the use of disease-free seed in a field, free of the pathogen, 2-3 year crop rotations, the use of resistant varieties and chemical sprays of the plants in the seedbed and in the field (Agrios, 1988). The fungicides most commonly recommended for control of *Septoria* spp. include maneb, maneb with zinc, zineb, captan, dichloran and Bordeaux mixture (Agrios, 1988).

2.3. Seed Supply Systems

Seeds are basic agricultural input. More importantly quality seeds of any preferred varieties are basis of improved agricultural productivity since they respond to farmers needs for both their increasing productivity and crop uses (Pelmer, 2005). In Africa, the majority of farmers mainly get their seeds from informal channels which include farm saved seeds, seed exchanges among farmers or/and local grain/seed market.

These channels contribute about 90-100 % of seed supply depending on the crop (Maredia *et al*., 1999). Despite the importance of this system; unlike the formal (regulated) seed systems, the informal is rarely supported. Subsequently, its improvement has been very limited or non-existent. Therefore, this has negative effects on agricultural productivity and income of farmers and more particularly to poor and marginalized farmers (Rubyogo *et al*., 2007). Nevertheless , it is has been proved that once well supported and linked to sources of improved varieties, the informal seed sector can be a reliable and efficient way to access improved varieties of crops whose seeds attract a very limited interest of commercial seed sector (Maredia *et al*., 1999).

Although a consensus is yet to be reached about the fundamental features of a sustainable seed system, clearly a functional seed system of some form is essential to sustain seed security. Maredia and Howard (1998) present a reasonably comprehensive outline of the elements that comprise a seed system. Their model is composed of organisations, individuals and institutions involved in different seedrelated functions. These functions involve research and development, seed multiplication, seed processing and storage, and seed marketing and distribution. Both the informal and formal sectors contribute to these five functions but Maredia and Howard (1998) system is more informative about the role of the formal sector than about the informal sector. The authors acknowledge that the informal sector has been grossly under-supported and that case studies are needed to examine the socioeconomic impact of smallholders on seed systems. Maredia and Howard (1998) argue that there is an evolutionary progression from a traditional informal system to an advanced market-driven seed system with appropriate laws and regulations to ensure national and regional seed security and to protect farmers who purchase seed. Earlier, Lanteri and Quagliotti (1997) had also proposed that a sustainable seed system must have a number of elements including research, seed multiplication, seed processing, seed storage and finally distribution and marketing. The authors offer a reservation that the ideal institutional structure for a seed system cannot be prescriptive because political and economic management systems and laws have a great influence on what is possible and achievable for any particular country. While all authors have difficulty in proposing a definitive seed system that is generally applicable, all are in agreement that an effective seed system can only operate if there is a functional informal seed sector as well as a formal seed sector (Lanteri and Quagliotti, 1997; Maredia and Howard, 1998).

2.3.1. Formal seed supply system

The formal sector is generally regarded as comprising public and private research and development of plant breeding and related aspects of seed physiology and plant disease, variety release, deliberate seed multiplication on 'seed farms', seed processing and storage, and seed marketing and distribution (Scowcroft and Polak Scowcroft, 1998).

The formal seed sector is frequently the driver that leads to the establishment of rules and regulations to manage variety release, quarantine, plant variety rights, seed certification, product labelling, marketing, pricing, consumer protection and so on (Rubyogo *et al*., 2007). The formal sector comprises national, regional and international agricultural research and policy organisations, private sector companies and business associations. This sector tends to be driven largely by government policy which is frequently influenced by national politics and international agreements. However, the formal sector provides the basis for effective regional negotiation and agreement to achieve regional seed security (Scowcroft and Polak Scowcroft, 1998).

This supply system generally consists of a research institution (mainly public), private seed production and marketing agencies and seed quality control organisations. In spite of reasonable successful seed programmes in many developing countries, the formal seed industry arrangements is reported to cater for less than 10% of the seed needs of the farmers (FAO, 1997b). The most important reason given for this is the fact that seed programmes have concentrated on major food and cash crops which are considered national priorities in terms of foreign exchange earnings and selected staple food requirements (FAO, 1997b).

The formal seed supply systems are generally represented by all official or organized seed production and supply programmes (FAO, 1997b). In Sub-Saharan Africa, the formal seed supply systems are carried out for the most part by the public sector, and are commonly assisted by donor agencies in the region (FAO and Accademia dei Georgofili, 1998). Private companies are also involved especially in Ethiopia, Madagascar, Malawi, Mozambique, Nigeria, South Africa, Zambia, and Zimbabwe. However, despite these efforts the formal seed supply systems are currently not meeting more than 5-10% on average of the seed needs of farmers in the region (FAO, 1997b). Furthermore, this low rate covers only the most commercialized crops and, to some extent, the main cereal crops. For other food crops, especially vegetables, legumes, arid and semi-arid crops, and vegetatively propagated planting materials, there are few initiatives targeted at farmers so that they can benefit from modern crop improvement programmes (FAO and Accademia dei Georgofili, 1998).

2.3.2. Informal seed supply system

The informal seed sector has traditional roots. It refers to the collective efforts of farmers and their local communities who save and store part of their harvest for future planting, exchange seed with relatives and other farmers or trade seed in the local market place. These farmer-based and community-based seed acquisition and distribution channels form the basis of a dynamic, if well-defined, seed system (FAO and Accademia dei Georgofili., 1998).

The informal sector is characterised by a seasonal crop cycle involving crop production, empirical selection of desirable types, farmers harvesting, cleaning and storing their own seed, exchange of seed between family members and relatives, trade or barter in the local market place, planting and cultivation (FAO and Accademia dei Georgofili, 1998). Much of the information concerning agronomic performance, yield, disease resistance, quality, cultural preference and diversity of end users is communicated by word of mouth and is seldom, if ever, subject to rigorous experimental evaluation (FAO and Accademia dei Georgofili, 1998).

The informal seed sector has stood agrarian communities in good stead for centuries, even millennia, and has underpinned the evolution of agriculture throughout the world (Scowcroft and Polak Scowcroft, 1998).

A fundamental feature of the informal seed sector is the interrelationship of diversity and food security - the use of diversity at the genetic level, understanding diversity at the ecological level and sustaining diversity at the farm management level (FAO and Accademia dei Georgofili, 1998). Relatively recent analysis has led to an understanding of the crucially important role that women have played in sustaining the informal seed sector, and more widely, in sustaining food security (FAO and Accademia dei Georgofili, 1998).

The informal seed supply system has its roots in the age-old tradition used by farmers to ensure the supply of more than 90% of the planting materials of staple food crops required to meet food security (FAO, 1997b). This comprises mainly of on-farm production, selection and saving of grain, tuber or stalk from harvested crop as seed for the next cropping season. It also includes on-farm seed production surpluses, which are traded in the appropriate local markets in various forms (cash, barter or kind) (Rubyogo, *et al*., 2007).

The role of this system in germplasm conservation has been well documented (Scowcroft and Polak Scowcroft, 1998). Among the many qualities which made onfarm seed production a credible option for seed security of staple food crops are; Broader national coverage (FAO and Accademia dei Georgofili, 1998), maintenance and sustenance of many crops, which are not patronised by the formal seed supply system but which are vital to the survival of the majority of the people particularly the under privileged, reasonable and affordable seed costs to other farmers and availability of alternate arrangements for seed payment, inclusion of farmer's varietal preference in the production programme, closeness of seed supply sources to cultivators, and stability of crop yield through the use of genetically broad-based varieties or ecotypes (FAO and Accademia dei Georgofili, 1998). However, because the informal sector largely depends on local resources and inputs, seed supply at this level can be very vulnerable to disaster and socio-political disruption. In such cases, NGOs frequently provide strong support to farmers and local communities.

2.3.3. Inter-relationship of the informal and formal seed sectors

Ideally, the formal and informal seed sectors should be complementary and highly interactive. However, reality is far from this ideal. In many cases, the formal and informal systems operate essentially as separate and non-interacting entities (Cromwell *et al*., 1993). Currently it is difficult to gain an overall picture of the relative importance and role of the formal and informal sectors. For Africa, a number of analyses have shown that there is a wide diversity in how the two sectors interact

(Cromwell *et al.*, 1993; Tripp *et al.*, 1997; Lanteri and Quagliotti, 1997; Maredia and Howard, 1998; FAO, 1998).

Tripp *et al.* (1997) reported on how developing country authorities have failed to come to grips with regulatory reforms for both the formal and informal seed sectors. The authors concluded that seed regulatory reforms, variety testing and regulation, and seed quality control is unsatisfactory because, seed regulation is poorly organised, inappropriate standards are used, there is little or no opportunity for farmer and seed producer involvement, and the seed regulatory process is not transparent (Tripp *et al.*, 1997). A number of factors lead to this unsatisfactory situation. These include decreasing national budgets for public sector research and declining donor support for long-term breeding and variety development. There is also concern about erosion and control of plant genetic diversity, pressure to establish plant variety rights, emergence of variety development and seed production at the local level and the collapse of a number of parastatal seed organisations (Tripp *et al.*, 1997).

Considerable resources have already gone into strengthening the formal seed sector particularly in Africa. According to Maredia and Howard (1998), The World Bank has supported more than 40 seed projects in Africa. USAID has provided long-term support to the public seed sector in more than 50 countries and FAO has invested US$80 million in over 100 seed projects in 60 countries. Most of these resources were used to support large scale parastatal seed companies and the infrastructure necessary to sustain them (FAO and Accademia dei Georgofili, 1998).

Many of these parastatal organisations have only achieved limited success and some of them are being privatised or disestablished. In the absence of continued donor support, parastatals have had great difficulty in surviving (Rubyogo, *et al.*, 2007). The private sector aspect of the formal seed system has focused on those species and crops that show a profit. The private sector, along with the parastatals, has tended to focus on breeding, production and sales of hybrids especially maize, sunflower and sorghum, some vegetable crops and commercial food crops, fibre and cash crops suitable for export rather than domestic consumption (Scowcroft and Polak Scowcroft, 1998).

In the general absence of Plant Breeders' Rights or other forms of intellectual property (IP) protection in Sub-Saharan Africa countries, it is simply not economic for private companies to market self- or open-pollinated varieties (FAO and Accademia dei Georgofili, 1998).

The informal sector, on the other hand, has concentrated on those crops and seed systems which underpin local food production. This includes crops that are predominantly self-pollinating but also including open pollinated crops, have a sowing rate greater than 35 kg per hectare with a coincident low to medium multiplication rate, and which store reasonably well (Rubyogo, *et al*., 2007).

The informal sector is almost solely responsible to ensure the sustainable supply of propagating material of asexually propagated food crops such as cassava, plantain, yams, potato and sweet potato. This important role of the farmer and communitybased seed sector is often overlooked when seed systems are viewed from the perspective of commodity crop production (FAO and Accademia dei Georgofili, 1998).

It is very significant that a number of authors indicate that the predominant source of planting seed used by small farmers is from self-stored seed or is obtained by purchase or barter from local sources (FAO and Accademia dei Georgofili, 1998). Only a small percentage is obtained from the formal sector and this is mostly maize and sorghum (FAO and Accademia dei Georgofili, 1998). The percentage of seed obtained by farmers from the informal seed system is high, estimated at 85% for Ethiopian farmers (Tafesse, 1998) and 90% for Africa as a whole (Lanteri and

Quagliotti, 1997). Even in the technically more advanced Southern African Development Community (SADC) region, on-farm seed multiplication and farmersaved seed constitute 95-100% of planting seed used for open pollinated maize, sorghum, millet, food legumes, roots and tuber crops (Wobil, 1998). Again, the formal sector concentrates on hybrid seeds, particularly for crops with low seeding rates.

It appears that there is overwhelming dependence on farmer and rural communitybased seed supply systems to sustain crop production and, therefore, food security. However, it is premature to be definitive about small-scale farmer seed practices throughout Africa because of the limited analyses that have been conducted (Walker and Tripp, 1998).

Thus, the development of national seed policies must devote more effort to sustaining and strengthening the informal seed sector. Past international support to strengthen seed systems focused on the formal seed sector. Now it is very essential that international support for sustainable seed systems in Sub-Saharan Africa provide adequate or matching support to the informal sector (FAO and Accademia dei Georgofili, 1998).

3.0. Materials and Methods

The research work covered the five ecological zones of Ghana in the major and minor seasons of the year 2009. The laboratory analysis was conducted at the Crop Research Institute (CRI) at Fumesua. The research was in two parts, a field survey and a laboratory analysis.

3.1. Field survey and sample collection

The research covered all the five ecological zones of Ghana. The five ecological zones of Ghana were the Coastal Savannah, Forest, Transition, Guinea Savannah and the Sudan Savannah zones.

A preliminary survey was conducted in the middle of the major cropping seasons to identify Seed Producers/Farmers and the main crop seeds produced in the five ecological zones of Ghana. From each ecological zone, three districts were covered.

From each district three locations (town/village) popularly known for the production of maize and/or cowpea crops were covered, and from each location two farmers were identified for the survey and seed collection. The seed samples were collected after the seed was harvested and processed in the case of certified seed and farmersaved seeds. Some seeds were collected from the market where the market was one of their main sources of planting seed in that location. One kilogram primary sample was taken from each selected farmer per location. The initial moisture content of the seed samples were recorded using moisture meter, then labelled and put in plastic bags and air-tightly sealed then stored at room temperature (25°C) in transit for seed health analysis at Crop Research Institute. Seed samples of above storable moisture content were dried further before storage. Seed samples were stored in a cold room of 10 to15°C for good preservation prior to laboratory analysis.

A simple questionnaire focusing on a wide range of seed management activities was designed (appendix C). On completion of the questionnaire, each farmer was requested to provide a sample of the seed which the farmer had stored to plant or for sale. Each of the seed samples was labelled as follows; Name of farmer, Ecological zone, District, Location, Crop/Variety, Seed type, and Date of harvest.

3.2. Laboratory Analysis

The seed quality analyses were conducted at the Seed Pathology laboratory of Crop Research Institute at Fumesua near Kumasi and Grains & Legumes Development Board's seed laboratory in Kumasi. Completely Randomised Design (CRD) was applied in all trials in the laboratory.

3.2.1. Working sample

Working samples of 900g and 400g were weighed from each of the maize and cowpea submitted samples respectively by using the repeated halving method (ISTA, 2007). The submitted sample was passed through a conical divider, recombining the parts and passing the whole sample through a second time, and similarly, a third time when necessary. The sample was reduced by passing the seed through repeatedly and removing part on each occasion. The process of reduction was continued until a working sample required was obtained (ISTA, 2007).

3.2.2. Purity analysis

The working sample was weighed and visually separated into its component parts of pure seed, other seeds and inert matter. Each component part was weighed for which percentage calculated using the equation below.

$$\% \ cccccccccccccccccc \ ccppppcc = wwccwwwwhcc \ ccoo \ ccccccccccccccccc \ ccppppcc \div TTccccppTT \ wwccwwwwhcc \ ccoo \ ssppccccTTcc$$

The procedure was repeated for all the samples.

3.2.3. Germination test

Four hundred seeds were counted at random from the well-mixed pure seed. Using the counting board replicates of 100 seeds were placed on wet double paper towel. A single wet paper towel was used to cover the seeds, rolled and held intact with rubber bands. The replicates were placed on trays in a cabinet germinator. The relative humidity was maintained at very near saturation by placing a tray of water at the base of the cabinet. The temperature of the germinator was maintained between 20^{o} and 30^{o}C. First count was done on the fourth and fifth days and final count on seventh and eighth days for maize and cowpea respectively. The procedure was repeated for each sample (ISTA, 2007).

3.2.4. Seed vigour

The seed vigour was calculated from the first count of the germination test in 3.2.3.

% *Seed vigour = First count* ÷ (*Total number of seed tested*) x *100*

3.2.5. Seed health test

The purpose of the seed health test was to determine seed fungal infections of the samples. The seed samples were analysed using the Blotter method (ISTA, 2007). On a clean working table sterilised with sodium hypochlorite ($NaOCl_2$), the required numbers of new Petri dishes (9cm diameter) per sample were collected and accession number of each sample and date of inspection written on the cover. Sets of three filter papers were counted, dipped in distilled water to ensure total wetness and placed in the lower dish. The pure seed was poured in to a tray and with a table spoon, small portions of seeds were taken at random onto working table. Seed counts of 10 for maize and 10 for cowpea were used to plate the dishes at equidistance from each other and in a circle with a central seed using biceps. 400 seeds of 100 per replicate were used for each sample (Mathur and Kongsdal, 2003; ISTA, 2007). All the dishes of each sample were gently collected on one tray and transferred to the incubation room. The dishes of seed samples were incubated at a temperature of 22^{o}C for 24 hour in alternate cycle of 12 hours darkness and 12 hours light. The dishes were then transferred to a deep-freezer and frozen at -20°C for twelve hours.

The dishes of seed samples were then returned to the incubation room and incubated to add up to 7 days in alternating cycles of 12 hours darkness and 12 hours light. The source of light used in the incubation room was near ultraviolet supplied by black light tubes (ISTA, 2007).

After incubation the dishes were removed and numbered serially. Moving from one Petri dish to the other, each seed was examined under a stereo microscope. Habit characters of each fungus were observed to identify the fungus. Slide preparations of fruiting structures of certain fungi were made to further confirm their identities. The abbreviation for the identified fungus was written against each seed on the wet blotter. Counting of the different fungi in each Petri dish was done by crossing abbreviations. Count of each fungus from each dish was entered in working recording sheet immediately after examination of the dish (ISTA, 2007).

3.2.6. Isolation of the pathogens

The fungal pathogens identified during the examinations under microscopes were isolated using Kocks postulate, into pure cultures for preservation and for further studies. Sterilised Petri dishes were used. The medium for the isolation was prepared by weighing 3.9g of potato dextrose agar (PDA) and mixed with a litre of distilled water in Pyrex bottle under the Laminar Flow Workstation. The mixture was then autoclaved for 15 to 20 minutes at 121°C at 15Ib/pressure and removed back to the Laminar Flow Workstation and allowed to cool down to around 50°C.

Approximately 15ml was then poured into each Petri dish and allowed to solidify for 24 hours. Using the alcohol lamp, the pin was sterilised and used to pick small inoculums. The inoculums were plated on the PDA in the Petri dishes and incubated for 4 days. The samples were then examined and sub-cultured on PDA, incubated for another 4 days then examined. The pure culture of the pathogen was preserved in the refrigerator at 5°C (Mathur and Kongsdal, 2003).

3.3. Data analysis

Statistical analyses of data were in two parts; Survey data analysis was by SPSS version16 software. Laboratory data analysis was by GenStat 7.2 Discovery Edition statistical software using CRD in ANOVA.

4.0. Results

4.1. General information on farmers

The age distribution of farmers is presented in table 4.1 below. The Transition zone registered the highest percentage of 55 for age group 40-50 years. The Sudan Savannah had 50% of the farmers ageing beyond 50 years, however, the Forest zone showed the highest percentage of 44 in the age group 30-39 years among all the zones. Only the Transition and the Guinea Savannah zones had age group 18-29 years involved in farming but with relatively low percentages of 11.

The gender of farmers skewed towards males across all ecological zones as shown in Table 4.1 below. Guinea Savannah had no female farmer, with only 6% for Coastal Savannah zone. The rest of the ecological zones had 11% female farmers respectively.

Table 4.1:General information on farmers in the five ecological zones

		Ecological zones of Ghana					
Farmers		**Coastal Savannah (%)**	**Forest (%)**	**Transition (%)**	**Guinea Savannah (%)**	**Sudan Savannah (%)**	**Mean (%)**
Age groups (years)	18-29	0	0	11	11	0	**4.4**
	30-39	22	45	22	17	22	**25.6**
	40-50	39	33	56	39	28	**39.0**
	>50	39	22	11	33	50	**31.0**
Gender	Female	6	11	11	0	11	**7.8**
	Male	94	89	89	100	89	**92.2**

Education	No formal	17	22	22	83	67	**42.2**
	Primary	0	11	0	11	6	**5.6**
	Secondary	61	39	56	6	17	**35.8**
	Tertiary	22	28	22	0	10	**16.4**

The Guinea Savannah zone had the highest percentage of 83 of farmers without formal education, followed by the Sudan Savannah zone with 67% (Table 4.1). In the case of secondary (JHS/SHS) or form four level (MSLC), the Coastal Savannah zone showed the highest percentage of 61 followed by the Transition zone with percentage figure of 56%. Except for the Guinea Savannah zone, the rest of the ecological zones had some farmers who had attained tertiary level of education. Although the percentages registered for the tertiary level of education in the four ecological zones were relatively low, the Forest zone had the highest percentage of 28%. The Forest and Guinea Savannah zones each had 11% of farmers with only primary education, and 6% for the Sudan Savannah zone.

4.2. Seed management practices of farmers

The kind of seed used by farmers in their farming activities is presented in Figure 4.1. Farmers using saved-seed dominated with more than 50% across all the ecological zones except Coastal Savannah zone with 22% usage. The Transition zone had the highest percentage of 67 farmers using saved-seeds. The highest percentage of certified seed usage was 33% found in the Coastal Savannah zone of Ghana, with similar percentage usage of foundation seed in the same zone but none in the Guinea Savannah zone. The lowest percentage of farmers using certified seed was 11% in the Sudan Savannah zone. Highest usage of a mixture of certified and saved seed (28%) was realised in the Guinea Savannah zone.

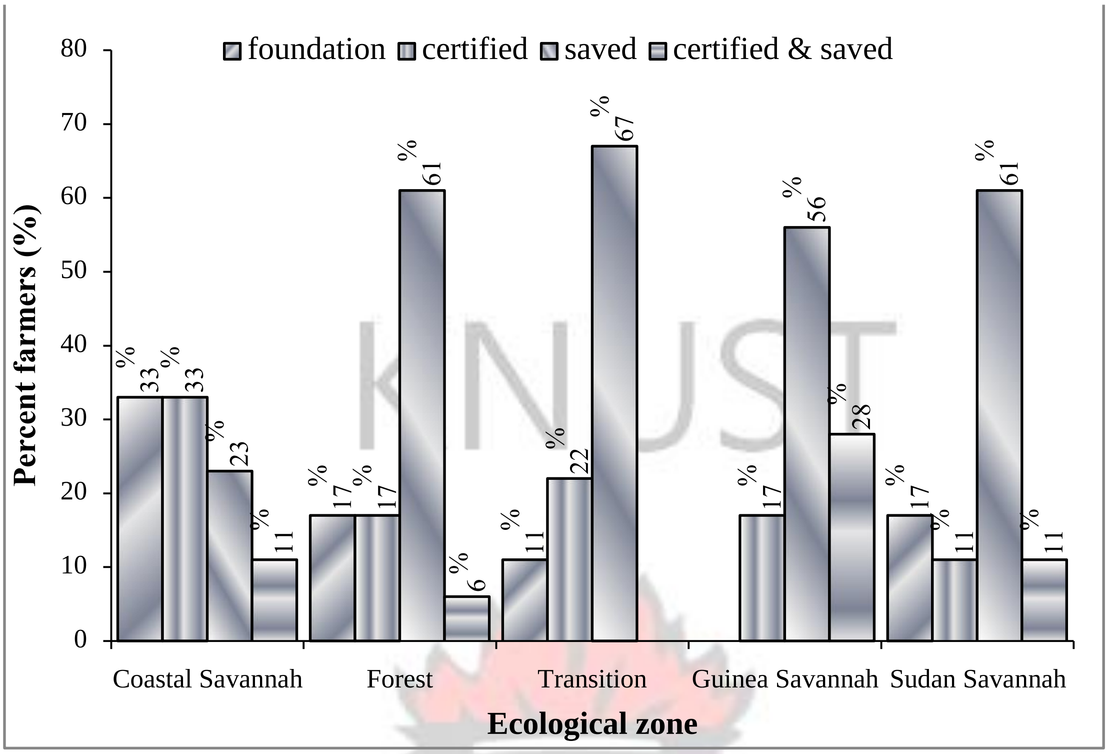

Figure 4.1: Kind of seed used by farmers in the five ecological zones of Ghana

The method of seed storage practiced by farmers in the five ecological zones is presented in Figure 4.2. In the Sudan Savannah zone 94% of farmers used store rooms for seed storage and 89% in the Guinea Savannah zone. However, in the Forest zone 44% of farmers preferred the use of locally made sheds or silos for seed storage with equal percentage storing no seed at all. Cold room storage was mainly practiced in the Coastal Savannah, Transition, and the Forest zones with farmer percentages of 33, 11 and 6 respectively. Seed storage in the open place recorded a very low percentage of 11 in the Forest and Guinea Savannah zones.

The practice of seed treatment before storage is presented in Figure 4.3 below. Insecticide was the only chemical used in all cases for seed treatment before storage across the five ecological zones recording same percentages as the treatments'.

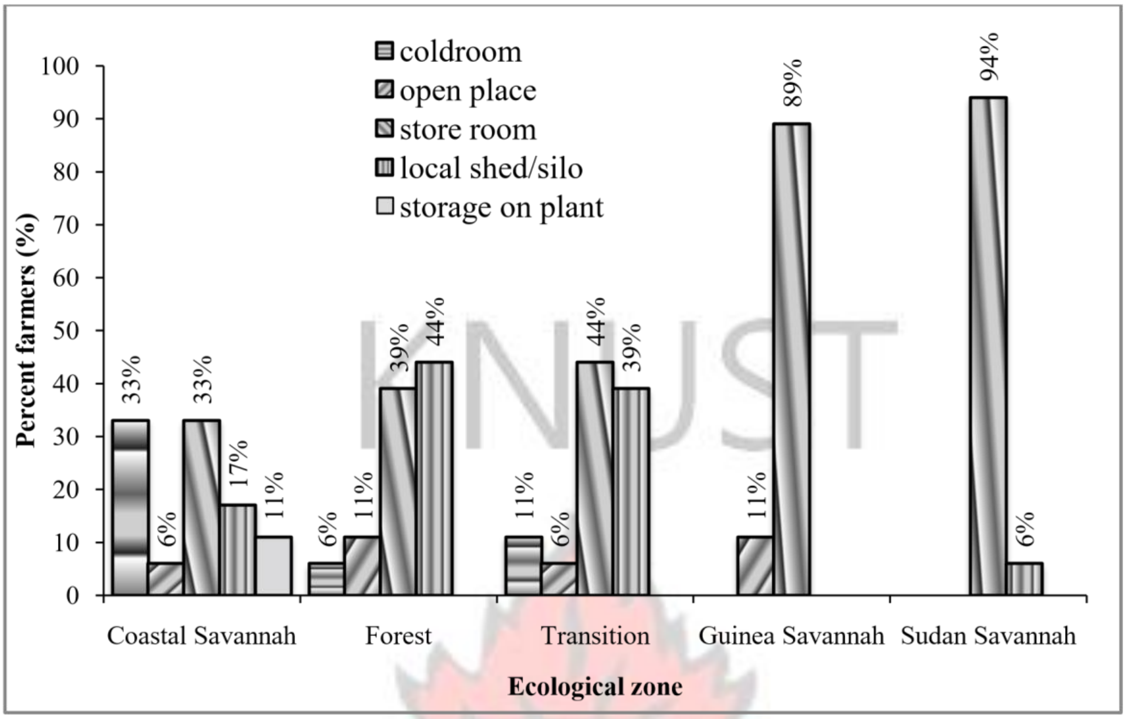

Figure 4.2: Method of seed storage in the five ecological zones of Ghana

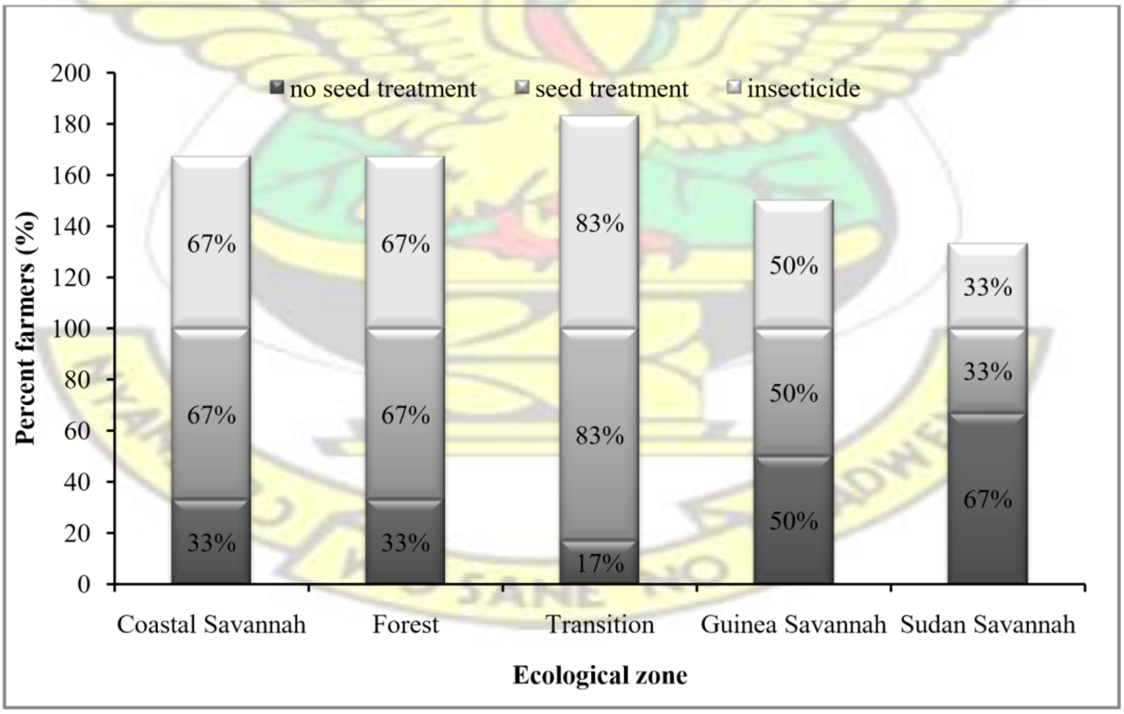

Figure 4.3: Seed treatment by farmers before storage practice in the five ecological zones of Ghana

The Transition zone had the highest with of 83% of farmers practicing seed treatment before storage whereas the Sudan Savannah zone had the least percentage of 33 with the rest of the ecological zones showing 50% and above of farmers who practiced seed treatment.

The incidence of diseases and pests during the fruiting stage of maize was highest in the Transition zone with 78% of farmers (Table 4.2). The least was 17% in the Coastal and Guinea Savannah zones of Ghana while the Sudan Savannah showed none. Disease and pest incidence before flowering was highest in the Guinea Savannah zone with 72% of farmers and lowest of 6% in the Forest zone.

Table 4.2: Seed management practices of farmers in the five ecological zones

		Ecological zones of Ghana					
Farmers		**Coastal Savannah (%)**	**Forest (%)**	**Transition (%)**	**Guinea Savannah (%)**	**Sudan Savannah (%)**	**Mean (%)**
Disease incidence	Before flowering	11	6	11	72	44	**28.8**
	Fruiting stage	17	61	78	17	0	**34.6**
Mode of seed processing	Manual	67	56	17	72	44	**51.2**
	Manual& machine	33	44	83	28	56	**48.8**
Maize yield range per 0.4 ha	<5maxi	33	11	11	50	6	**22.2**
	5-10maxi	67	83	56	44	72	**64.4**
	>10maxi	0	6	33	6	22	**13.4**

Storage duration (months)	0-6	89	89	94	89	39	**80.0**
	7-12	11	11	6	11	61	**20.0**

The Coastal Savannah zone recorded the highest of 72% of farmers without any disease incidence, while the least were Transition and Guinea Savannah zones each with 11% of farmers.

Table 4.2 presents the mode of seed processing as practiced by farmers in the five ecological zones. The use of hand in all stages of seed processing was highest in the Guinea Savannah zone with 72% of farmers. Although the Transition zone had the least percentage of 17 farmers processing seed manually, the zone also registered the highest percentage with 83 of farmers using both manual and machine for seed processing.

The maize seed yield per hectare for farmers in the five ecological zones is presented in Table 4.2 with Forest zone having the highest percentage with 83% of farmers within the yield range of 5-10 maxi-bags/0.4ha (maxi-bag=100kg). The least 5-10 maxi-bag yield per 0.4ha was 44% farmers in the Guinea Savannah zone and the rest recorded above 50%. The Transition zone recorded 33% of farmers who obtained more than 10 maxi-bags seed yield. The Guinea Savannah zone recorded highest percentage of farmers (50%) who obtained below 5 maxi-bags of seed yield, the least being 6% of farmers in the Sudan Savannah zone. The percentage of farmer practicing storage periods of 0-6 months was observed in all the ecological zones with the Transition zone recording the highest farmer percentage of 94%, and the Sudan Savannah zone with the least percentage of 39%. The Sudan Savannah zone however recorded the highest percentage of farmer (61%) storing seed between 712months.

The cowpea farm size ranges in hectares for farmers in four ecological zones of Ghana is presented in Figure 4.4. The Forest zone had the highest percentage of farmers (61%) who did not crop cowpea. Farmers who cropped 0.4 to 2 hectares were highest in the Guinea Savannah zone with percentage of 61% and the least of 17% in the Forest zone which also had the highest of six to 4 hectare range with 11%.

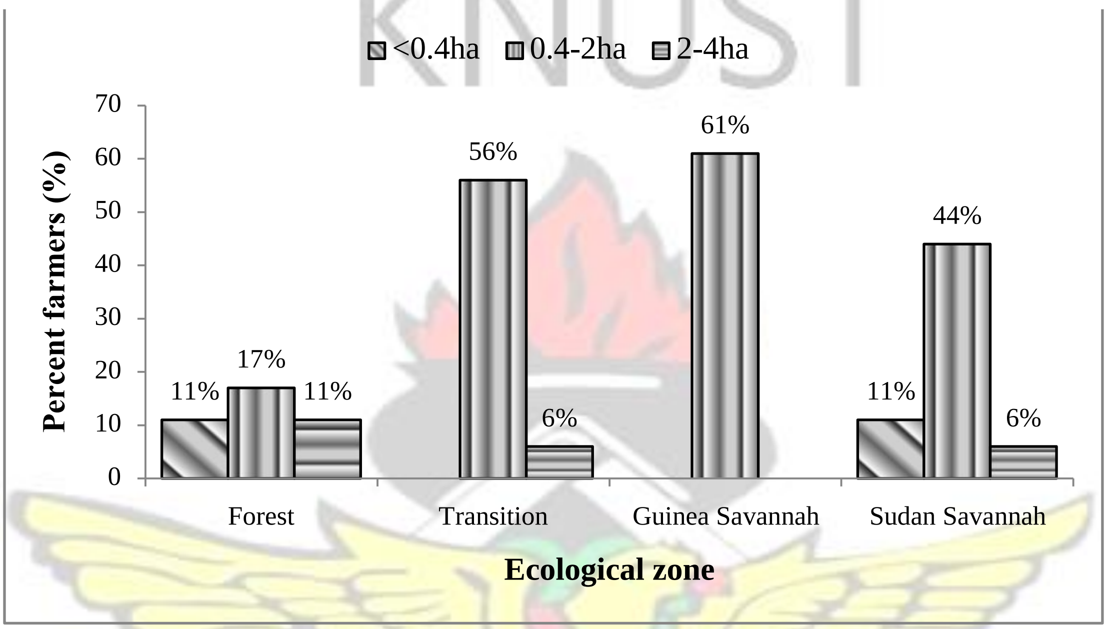

Figure 4.4: Percentage cowpea farm size distribution in hectares for the four ecological zones of Ghana

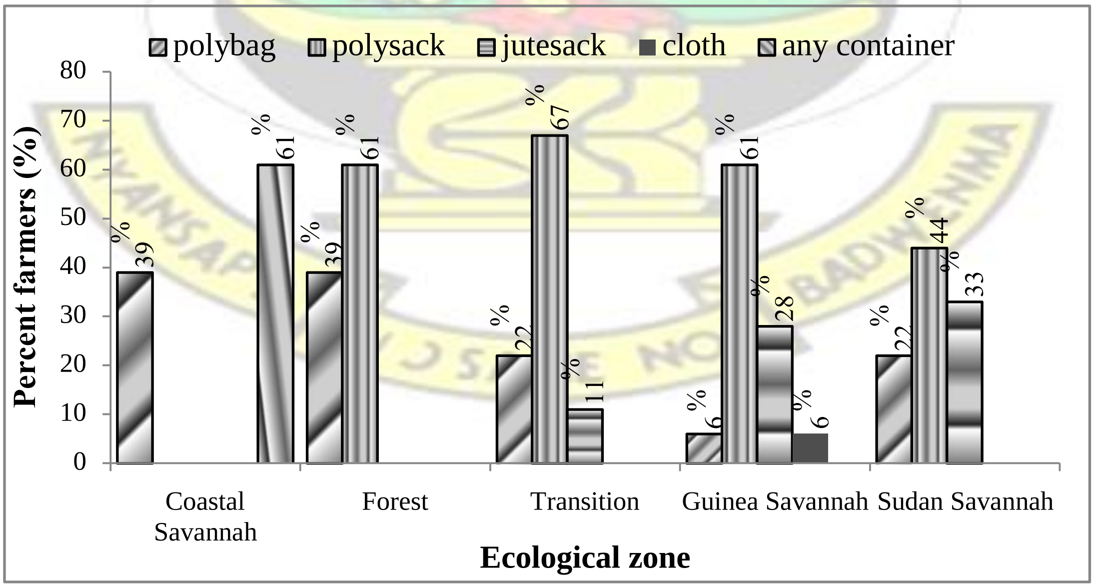

Figure 4.5: Material for seed packaging in the five ecological zones of Ghana

The presentation in Figure 4.5 shows how the farmers in the five ecological zones of Ghana packaged seeds. The use of poly-sack dominated in all the ecological zones reaching a peak of 67% in the Transition zone, except the Coastal Savannah zone which had no farmer using poly-sack for seed packaging. The Coastal Savannah was however the only zone which had 61% of farmers using any container for seed packaging. The Sudan Savannah zone had highest farmer usage of jute-sack for seed packing of 33% followed by the Guinea Savannah and Transition zones with percentages of 28% and 11% respectively. The use of polypropylene bags for seed packaging was a common practice across all the ecological zones but recorded the highest percentage of 39 in both Coastal Savannah and the Forest zones of Ghana with the Guinea Savannah zone having a low of 6%. The use of cloth for seed packaging was a practice only in the Guinea Savannah zone with a low of 6%.

4.3. Laboratory results of seed maize samples

The results from the laboratory analyses are presented in bar graphs and tables covering seed health, vigour, germination and moisture content tests.

4.2.1. *Fusarium moniliforme*

The occurrence of *Fusarium moniliforme* was highest in the Transition zone with a mean incidence of 49.4%, significantly different (p=0.05) from the least found in the Coastal Savannah zone and the Forest zones. However, there was no significant difference between Coastal Savannah and Forest zones in terms of *Fusarium moniliforme* (Figure 4.6). The mean percentage incidence for the Sudan Savannah zone was 44.5 and 40.7 in the Guinea Savannah zone.

4.2.2. *Botryodiplodia theobromae*

The incidence of *Botryodiplodia theobromae* in the ecological zones is presented in Figure 4.7 below. The highest occurrence of 10.3% was in the Sudan Savannah zone significantly different ($p<0.001$) from the rest of the ecological zones. The lowest incidence of 1.8% occurred in the Transition zone of Ghana. The Guinea Savannah zone had incidence of 6.1% being the second highest followed by the Forest zone with 4.6% incidence and then the Coastal Savannah zone with percentage incidence of 2.3.

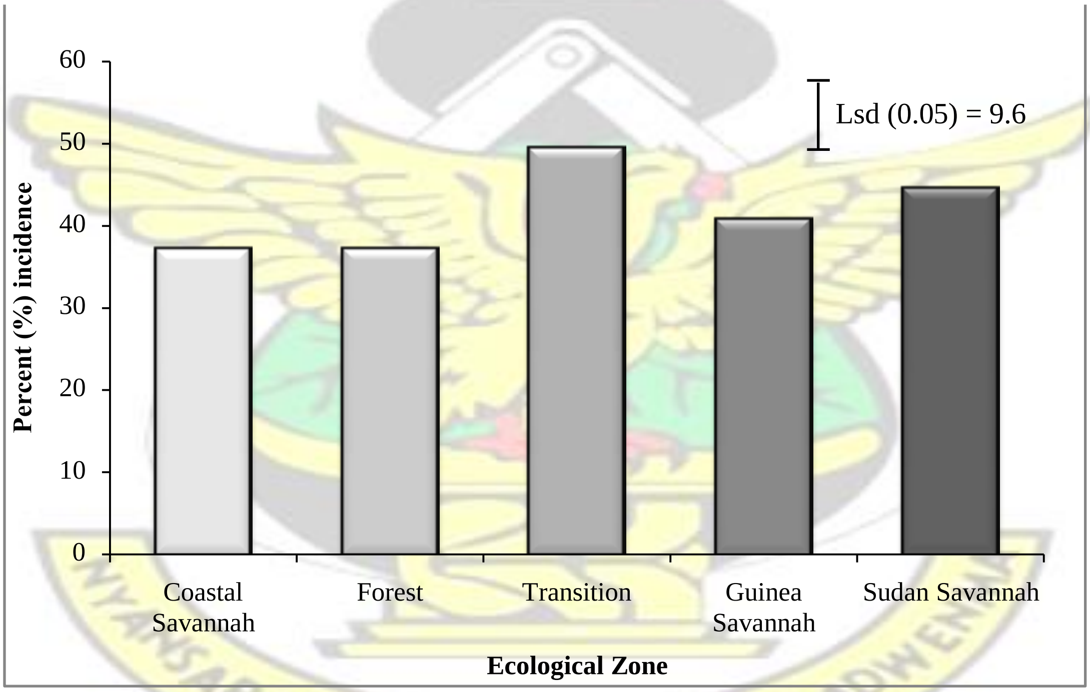

Figure 4.6: Percentage incidence of *Fusarium moniliforme* in the five ecozones of Ghana

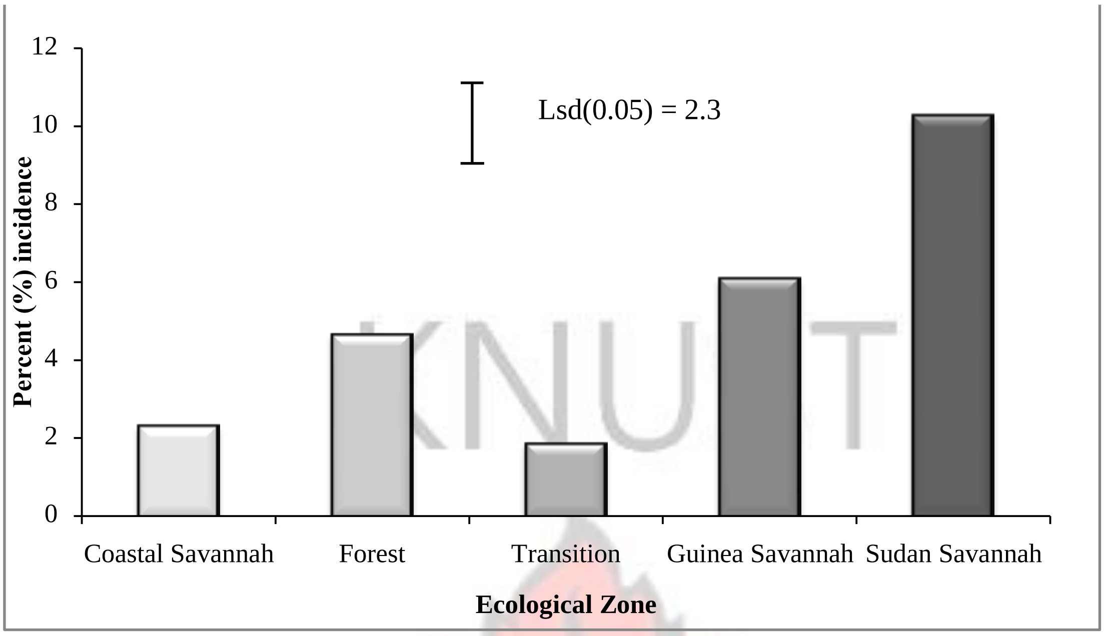

Figure 4.7: Percentage incidence of *Botryodiplodia theobromae* in the five ecozones of Ghana

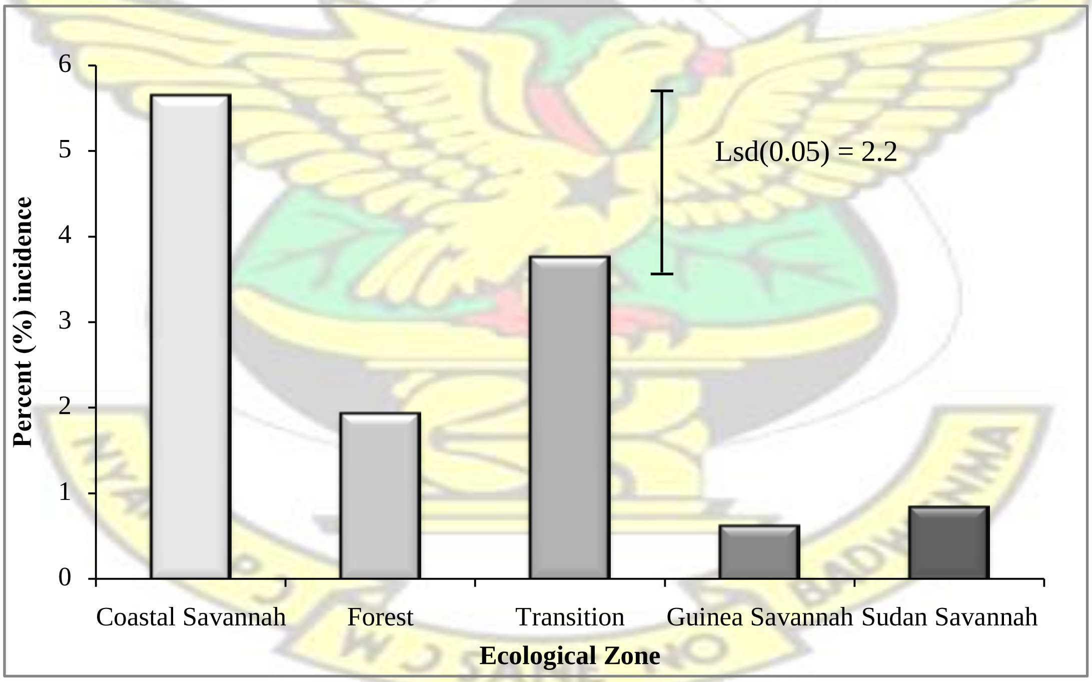

Figure 4.8: Percentage incidence of *Acremonium strictum* in the five ecozones of Ghana

4.2.3. *Acremonium strictum*

Incidence of *Acremonium strictum* in the five ecological zones are presented in Figure 4.8 above. The highest incidence of *Acremonium strictum* occurred in the Coastal Savannah zone with percentage of 5.6 significantly different ($p<0.001$) from the Forest (1.9%), the Sudan Savannah (0.8%) and the Guinea Savannah (0.6%) zones. The next highest incidence was in the Transition zone with incidence of 3.8%.

Table 4.4: Percentage incidences of *Fusarium pallidoroseum* and *Bipolaris maydis* in the five ecozones of Ghana

Ecological zone	***Fusarium pallidoroseum***	***Bipolaris maydis***
Coastal Savannah	0	0
Forest	0	0.056
Transition	0.028	0
Guinea Savannah	0.083	0.139
Sudan Savannah	0	0
LSD @ 5%	0.068	0.133
CV (%)	656.3	732.3

4.2.4. *Fusarium pallidoroseum*

Fusarium pallidoroseum incidence occurred in Forest and Transition zones of Ghana with 0.03% and 0.08% respectively. These showed no significant difference from each other. These are presented in Table 4.4 above.

4.2.5. *Bipolaris maydis*

The Forest and Guinea Savannah zones were the only ecological zones with incidence of *Bipolaris maydis*. The occurrences were 0.06% and 0.14% respectively, showing no significant difference. These are presented in Table 4.4 above.

4.2.6. Seed purity, vigour, germination and moisture content

The percentage seed purity, vigour, germination and moisture content of maize seed samples in the five ecological zones are presented in Table 4.5 below. The best pure seed percentage was 99.4 for Forest zone and the least was 96.6% for Coastal Savannah zone. The Guinea Savannah zone had the best germination percentage of 93.7 and vigour of 35% which were significantly different from the Forest, Transition, and Coastal Savannah zones. The Sudan Savannah zone had a germination of 91% and vigour of 28.7% and was not significantly different from Guinea Savannah in terms of germination percentage but different in terms of vigour.

The least moisture content of 10% was recorded in the Sudan Savannah zone and 11.2% in the Guinea Savannah zone significantly different from the Coastal Savannah (15.2%), Forest (16.3%) and Transition (16.3)% zones of Ghana.

Table 4.5: Percentage of seed purity, vigour, germination and moisture content of seed maize samples from the five ecological zones of Ghana

Ecological zone	Purity (%)	Vigour (%)	Germ (%)	MC (%)
Coastal Savannah	96.6	21.4	68.0	15.2
Forest	99.4	30.2	78.7	16.3
Transition	99.1	26.0	73.4	16.3
Guinea Savannah	99.2	35.0	93.7	11.2
Sudan Savannah	97.5	28.7	91.0	10.0

LSD @ 5%	1.2	4.13	6.01	0.58
CV (%)	2.6	44.6	22.6	12.9

4.3. Laboratory results of cowpea seed samples

The results for the cowpea blotter test is presented is Table 4.6. *Fusarium oxysporum, Macrophomina phaseolina, and Colletotrichum lindemuthianum* respectively showed significant differences between the four ecological zones of Ghana. No data was recorded for the Coastal Savannah zone.

4.3.1. *Fusarium oxysporum*

The incidence of *Fusarium oxysporum* in four ecological zones of Ghana is presented in Table 4.6 below. The highest incidence of 49.7% was in the Forest zone significantly different from the lowest percentage incidence of 14.3 occurred in the Sudan Savannah zone. The Transition zone was the next highest with the incidence of 41.6% and was not significantly different from 24.1% of the Guinea Savannah zone.

Table 4.6: Percentage incidences of seed-borne fungi of cowpea seed samples from four agro-ecological zones of Ghana

Ecological zone	*Fusarium oxysporum*	*Fusarium pallidoroseum*	*Macrophomena phaseolina*	*Colletotrichum lindemuthianum*
Forest	49.7	0	0	0
Transition	41.6	0	0.56	0.06
Guinea Savannah	24.1	0	0	0
Sudan Savannah	14.3	4.50	0	0

LSD @ 5%	25.77	2.563	1.085	0.1206
CV (%)	73.1	601.6	764.2	764.2

4.3.2. ***Fusarium pallidoroseum, Macrophomina phaseolina,*** **and** ***Colletotrichum lindemuthianum***

The only zone that recorded incidence of *Fusarium pallidoroseum* was the Sudan Savannah zone with a 4.5% and was significant. However, the Transition zone was the only zone which recorded both *Macrophomina phaseolina, and Colletotrichum lindemuthianum* having percentage incidence of 0.56 and 0.06 respectively. There were no significant differences. These are presented in Table 4.6 above.

Plate 4.1: Seed store room in the Northern part of Ghana

Plate 4.2: A Farmer storing seed in the Northern part of Ghana

Plate 4.3: Storage on shed in the Southern part of Ghana

Plate 4.4: Storage in the open place

Plate 4.5: Seed storage on plants

Plate 4.6: Seed storage in the cold room

5.0. Discussions

This chapter of discussion are in three sections. The first, discusses the survey analysis delving into seed management of the farmers sampled across the five ecological zones of Ghana. The second deals with the laboratory analyses of the samples from the five ecological zones of Ghana relating the incidence of fungal seed-borne pathogens, seed purity, vigour, germination, and moisture content of the ecological zones. The third discusses the farmers' social, cultural and general attitude to quality seed use and management, and fungal seed-borne pathogenic control.

5.1. Farmer gender profile and seed management of maize and cowpea

The general information on the farmers sampled across the five ecological zones revealed that, with the exception of 18-29 year age group the rest of the age groups were distributed across the five ecological zones. It was noted that in the northern part of Ghana (Guinea Savannah and the Sudan Savannah zone) more than 70% of farmers were above the age of forty, with 50% of farmers above the age of 50 in the Sudan Savannah zone (Table 4.1). The research revealed that, the youth below 40 years migrate to the southern Ghana for jobs and fertile farmlands mostly in the Transition zone. The rising importance of the transition zone as a source of maize supply can be attributed to a combination of factors, including the presence of favourable agro-ecological conditions, availability of improved production technology, a relative abundance of underutilized land, and a well-developed road transport system. The relative abundance of arable land in the transition zone has attracted many migrant farmers, particularly from the north of the country, who have moved to the zone to pursue commercial food farming (GGDP, 1991).

In the middle belt of Ghana (Transition zone) the age group 40-50 years dominated in maize and cowpea farming. The Transition zone appears to favour maize and cowpea production better recording the highest yield per 0.4ha of more than 10 maxi-bags (1000kg) hence the rush of the active age group into farming (Table 4.2). The Transition zone had more than 70% farmer having attained formal education to at the secondary (Junior High School-JHS/Senior High School-SHS) or form 4 levels (Middle School Leaving Certificate-MSLC) (Table 4.1). Just about 11% of the 18-29 year age group were involved in farming which the research found out to be mostly migrants from the Guinea and Sudan Savannah zones who had found fertile soils to farm after basic school. In the Forest zone the youth group of 30-39 years dominated farming, but the trend was different in the Coastal Savannah zone where the dominant age group were 40 years and above, with more than 80% having attained secondary (JHS/SHS) or form-4 level (MSLC) in education (Table 4.1).

It was evident that maize and cowpea cultivation in Ghana is a job reserved for men. In all the five ecological zones very negligible percentage of farmers, not exceeding 11.1% were found to be female. That was a confirmation of the fact that most farms are owned by a household with men as the head of the family, hence the owner of the farm (Table 4.1), and also due to labour intensiveness nature of such farming, the males are well needed.

Since the use of foundation seed is a preserve for certified seed producers, the farmer percentages of 33.3 in the Coastal Savannah as the highest foundation seed users was an indication of high certified seed producers in the zone (Figure 4.1) The potential benefits from the distribution and use of good quality seed of improved varieties are enormous, and the availability of quality seed of a wide range of varieties of crops to farmers is key to achieving food security in Ghana (Wright and Tyler, 1994).

Enhanced productivity, higher harvest index, reduced risks from pest and disease pressure, and higher incomes are some of the direct benefits potentially accruing to farmers (Wright and Tyler, 1994). Generally all the zones had certified seed producers except the Guinea Savannah zone where none were identified. Where cold rooms were available such as in the Coastal Savannah, Forest and the Transition zones the seed producers were the only farmers using the cold room storage facilities (Plate 4.6). Invariably, the use of farmer-saved seed was exceptionally high across four ecological zones with between 55% and 67%. In Africa, the majority of farmers mainly get their seeds from informal channels which include farmer-saved seeds, seed exchanges among farmers and local grain market. These channels contribute about 90-100 % of seed supply depending on the crop (Maredia *et al*., 1999). Coastal Savannah recorded the lowest use of farmer-saved seed of 23% (Figure 4.1) and this might be due to a high literacy level of the zone and easy accessibility to certified seed.

In the case of the Forest zone, though literacy level was high the use of farmer-saved seed was rather high at 61%. It was observed during the survey that certified seed was inaccessible to most of the farmers and they had to travel to a market centre to access it. The unit cost of the seed was thus increased beyond the farmers' affordable level. Few farmers (6%) managed to buy small quantity of certified seed and mixed it with their saved seed. It was also observed that some of the farmers by using certified seed for one season, used saved seeds continuously for three to four seasons before accessing fresh certified seed. In the Guinea Savannah zone the practice was among 28% farmers, the highest of all the ecological zones. The percentage of seed obtained by farmers from the informal seed system is high, estimated at 90% for Africa (Lanteri and Quagliotti, 1997).

The Transition zone had the highest percentage of farmers (67%) using saved seed. This zone though had quite high literacy level, preferred the use of their local variety to the improved varieties, hence the popular use of farmer-saved seed in the zone. The reasons for the use of their local variety as found from the survey were that, the local variety tasted better than the improved varieties and also stored better even without storage treatments. Rome declaration on world food security and the world food summit plan of action stated that, the principal strategy for sub-Saharan Africa to have food security is to strengthen the seed supply sector (FAO, 1997b).

In the Guinea and Sudan Savannah zones, the high use of farmer-saved seed was found to be inaccessibility as well as inability for the farmers to afford the price of the certified seed. Farmers from these two ecological zones mostly stored their seeds in store rooms (Figure 4.2) specially built with landcrete and roofed with thatch without a door or window. The seed was deposited in the store by lifting the whole roof or part of it. The store was designed in a circular shape with very smooth wall as in Plate 4.1. The reason for such storage store design was to prevent rodents from entering. It also helped to maintain the germ from dying due to more stable temperature within the store.

In the Guinea Savannah zone, seed storage was in the open place (Plate 4.4) but such practice was uncommon in the Forest, Transition and the Coastal Savannah zones. This storage practice was possible due to the low relative humidity associated with the zone; hence such open place storage according to the farmers enhanced drying.

Farmers in the Forest zone used sheds for storage of seed as in Plate 4.3. In the Transition zone a similar method was used by farmers to store seeds and in most situations gentle fire was set under the shed to prevent insect infestations and improve drying. In the Coastal Savannah zone farmers applied another method of seed storage by leaving the dry cobs on the plant until they were ready to be used or for sale as seen in Plate 4.5, but at a minimal rate (11%).

In all the five ecological zones, insecticide was the only chemical used for seed treatment before storage (Figure 4.3). This was because insects were their only concern. The Transition zone had over 80% of farmers treating their seed before storage. In the Sudan Savannah zone more than 60% of the farmers did not treat their seed before storage. It was observed during this study that in such zones where seeds were not treated before storage, the farmers were using part of the seed to feed their households.

Seed processing from harvest through to packaging is the most critical period in quality seed production. Manual seed processing was a common phenomenon across all the five ecological zones. In the Transition zone where over 80% of farmers processed seed by combination of manual and machine, the zone still had about 16% of farmers who used solely manual means of processing seed. Normally the machine used here was the maize shelling and winnowing machine. Cowpea was mainly processed manually.

The mode of seed packaging had been related to the kind of seed and in some situations the ecological zone. Certified seed was mainly packaged in polypropylene bags of 1kg and 2kg for marketing. The polypropylene sack of 100kg capacity was observed to be the most common material for packaging maize for market. Jute sack was also used to package seed in the Sudan and Guinea Savannah zones. This was so because of the low relative humidity of these zones. While the Forest zone would line the polypropylene sacks with polyethylene liners, it was not so in the Transition, Guinea and Sudan Savannah zones. Farmers in the Coastal Savannah zone preferred to keep the seed in storage until due for market when any container such as bowls, baskets, and sacks of any kind would be used for packaging. The Coastal Savannah farmers were noted for using much more certified seed than any of the zones hence the use of polypropylene bags as the major seed packaging material.

With the use of cloth as seed packaging material, very few farmers in the Guinea Savannah zone practiced this method of packaging.

5.2. Relationship between agro-ecological zones and fungal infestations of seed maize and cowpea

Fusarium moniliforme was detected in all the five ecological zones of Ghana and at highly significant levels. From the survey it was observed that this fungus which causes stalk rot, ear rot, and seed rot is assuming economic importance and should be given the necessary attention. Seed rot is most common in dry and warm weather conditions. *Fusarium moniliforme* is so widespread in maize producing countries that it can infect 100% of the seed. Its importance is further related to the production of mycotoxins, that a high incidence of *Fusarium moniliforme* in maize is positively correlated with a high rate of human oesophageal cancer (Patten, 1981). Incidence of *Fusarium moniliforme* is gradually assuming epidemic proportions due to its mode of transmission through the seed. The highest incidence was found in the Transition zone of Ghana with close to 50% spread (Figure 4.6). This zone also had the highest potential in maize production; therefore the economic importance of this fungus cannot be overemphasised. This explains why the same zone had the highest disease incidence (77.8%) before flowering and fruiting stages of maize (Table 4.2). The Guinea Savannah zone recorded infection of 40.7% and this reflected in the disease situation of the zone as high as 72.2% before flowering stage.

The Sudan Savannah was found to be leading in the incidence of *Botryodiplodia theobromae* (Figure 4.7) which causes black kernel rot in maize and is also a seedborne disease and therefore spreads unknowingly (Mathur and Kongsdal, 2003). The fungus was present in all the other ecological zones as well but at a low percentage infection.

Acremonium strictum, the causal fungus of kernel rot and black bundle disease (Mathur and Kongsdal, 2003), was very prevalent in the Coastal Savannah zone and across all the ecological zones (Figure 4.8).

Fusarium pallidoroseum incidence was generally in the Transition and Forest zones only, at very low percentages (Table 4.4). The fungus is the causal organism of stalk and root rot (Mathur and Kongsdal, 2003).

Bipolaris maydis causing southern leaf blight was found at very low percentage incidence in the Guinea Savannah and Forest zones only (Table 4.4).

Among the five ecological zones sampled across Ghana, the Forest zone was found to have all the five seed-borne fungi isolated. This shows that the environmental conditions of the Forest zone favour the development and sporulation of the seedborne fungal pathogens. The Forest zone has moist and humid environmental conditions associated with high temperatures suitable for fungal growth.

The health test of the cowpea samples revealed four major seed-borne fungi. These included *Fusarium oxysporum, Fusarium pallidoroseum, Macrophomina phaseolina* and *Colletotrichum lindemuthianum.*

The occurrence of *Fusarium oxysporum* on seeds was most prevalent in the Forest zone. The fungus which causes fusarium wilt was found in the Transition, Guinea Savannah, and Sudan Savannah zones as well (Table 4.6) but at low levels of infection. With the exception of *Fusarium oxysporum*, the percentage incidences of the other fungal pathogens in the cowpea samples in the Forest zone were rather low. The Sudan Savannah recorded the only incidence of *Fusarium pallidoroseum*.

However, the presence of high levels of *Fusarium pallidoroseum* is alarming since *Fusarium* spp. are known to produce mycotoxins (Agrios, 1988). The Transition zone alone recorded the other two fungi namely *Macrophomina phaseolina* and *Colletotrichum lindemuthianum*. *Macrophomina phaseolina* causes an economically important disease of cowpeas and beans, known as ashy stem blight or charcoal rot (Hagedorn, 1991). *Colletotrichum lindemuthianum* causes anthracnose (Mathur and Kongsdal, 2003), and was recorded at a very low percentage in the Transition zone. These fungal pathogens are reported of inducing losses in cowpea and are often considered to be a limiting factor in cowpea production (Richardson, 1979). This explains the low hectares of cowpea cultivation across the four ecological zones of Ghana shown in Figure 4.4, as a result of these diseases.

5.3. Fungal pathogenic effects on seed quality

All the ecological zones recorded low seed vigour percentages (Table 4.5). The germination percentages were also affected by the fungal infections which were in turn affected by seed management practices of the farmers. The moisture contents of seed samples for storage showed levels higher (Table 4.5) than the recommended level of 9-11% for maize (Anonymous, 1973) except in the Guinea and Sudan Savannah zones, where relatively higher germination percentages were recorded. The dryer environment associated with the Northern Ghana enhanced the moisture content of seeds from the Guinea and Sudan Savannah zones hence the seeds stored better than the humid environment in the Middle and Southern Ghana. Seed-borne pathogenic fungi may survive for long periods in storage and may attack seedlings during germination leading to poor emergence and a reduced seedling population. Pathogens may also be transmitted from the seed to the seedling causing disease symptoms and possible yield loss at a later stage of growth. Some seed borne diseases can multiply rapidly from one generation to the next and seed crops can also become infected from neighbouring diseased crops. In this way seed-borne disease can seriously affect the quality of both certified and farmer-saved seed (Wright *et al*., 1995).

Seed purity percentages were extremely high across the five ecological zones of Ghana. This explains the farmers' emphasis on physical quality of seed and lesser on health quality of the seed. In Ghana, seed certification and standards stipulate certification of seed as varietal purity, physical cleanliness, moisture content, and germination percentage (Anonymous, 1973).

Planting infected seed may also result in widespread distribution of disease within the crop, and allows for an increased number of initial infection sites early from which the disease can spread (Wright and Tyler, 1994).

6.0. Conclusions and Recommendations

6.1. Conclusions

The use of farmer-saved seed in Ghana was predominantly common across all the five ecological zones sampled. The issue to some degree is not that the farmers are not aware of the fact that improved seed use gives better yield, but because some do not have easy access to improved seed. Others also cannot afford the cost of improved seed. However, the few farmers who could afford certified seeds do not use them seasonally but rather at three to four seasons interval. The method of seed storage by farmers which is one of the major factors influencing seed quality, varied from one ecological zone to another. The practice of storing seed on the plant seems to be a bad practice since there is high tendency of pathogenic attacks on seed. It also subjects the seeds to fluctuating temperatures of day and night killing the germ. Such mode of storage also exposes the seeds to saprophytic fungal attack resulting in seed decay.

Considering the high levels of fungal seed-borne pathogenic infection of the seeds from the various ecological zones, moving seed across ecological zones will introduce new pathogens in new areas. For instance, *Fusarium pallidoroseum* was identified in the Forest and the Transition zones only but could spread to other parts of the country through exchanges in seed. Similarly, *Bipolaris maydis* could be introduced to the other three non-infected ecological zones from the Forest and Guinea Savannah zones where it was endemic.

The widespread incidence of *Fusarium moniliforme, Botryodiplodia theobromae* and *Acremonium strictum* in maize, and *Fusarium oxysporium, Macrophomina phaseolina* and *Fusarium pallidoroseum* in cowpea throughout the country call for critical attention to seed health regulations.

6.2. Recommendations

- A seed supply policy is needed to make seed accessible and affordable to deprived areas of the country.
- A seed quality programme should be put in place to ensure regular monitoring of food crop seeds for seed-borne pathogens in a seed quality surveillance activity.
- Seed health analysis should be included as part of seed certification in Ghana.
- There is the need for a seed law to be enacted and enforced in Ghana to regulate seed use in order to control the spread of seed-borne pathogens.
- There is the need to research into the use of extracts from botanicals for the control of these seed-borne fungal pathogens.
- Farmers should be educated to treat their seeds against seed-borne fungal pathogens before sowing.

7.0. References

Agrios, G. N. (1988). Plant Pathology. Third edition. Academic Press, Inc., New York.

Allen, D. J. (1983). *The Pathology of Tropical Food Legumes.* John Wiley & Sons, Chichester.

Anilkumar, T. B.; Chandrashekar, M.; Saifulla, M. and Veerappa, K. B. (1994). Assessment of partial resistance in cowpea cultivars to leaf spot (*Septoria vignicola* Rao). *Trop. Agric*. **71**: 36-40.

Anonymous (1973). Seeds (Certification and Standards) Regulations. National Redemption Commission, Ghana Government, Accra, Ghana (LI. 802).

Boyhan, G. E., Granberry, D. M., and Kelly, W. T. (1999). Southern peas. The University of Georgia, College of Agriculture and Environmental Sciences Georgia, United States, pp 1-4.

CIMMYT (2004). The CIMMYT Maize Program 2004. *Maize Diseases: A Guide for Field Identification.* 4th edition. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

Cromwell, E., Wiggins, S. and Wentzel, S. (1993). Sowing beyond the State: NGOs and seed supply in developing countries, ODI, London, pp.142.

De Mooy, C. J. and Burke, D. W. (1990). External infection mechanism of hypocotyls and cotyledons of cowpea seedlings by *Macrophomina phaseolina. Plant Disease* 74: 720.

Emechebe, A. M. and Florini, D. A. (1997). Shoot and pod diseases of cowpea induced by fungi and bacteria. Pages 176-192 in: Singh, B.B., Mohan Raj, D.R., Dashiell, K.E. & Jackai, L.E.N. (eds.) *Advances in Cowpea Research*. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS).

IITA, Ibadan, Nigeria.

FAO (1997b). Developing seed security strategies and programmes for food security in developing countries. Internal document of the Seed and Plant Genetic Resources Service of FAO, Rome, Italy.

FAO and Accademia dei Georgofili. (1998). Proceedings: International Workshop on Seed Security for Food Security. FAO, Rome and Accademia dei Georgofili, Florence, Italy.

GGDP. 1991. A Study of Maize Technology Adoption in Ghana. Mexico City, Mexico: Ghana Grains Development Project.

Hagedorn, D. J. (1991). Ashy stem blight. In: Hall, R (ed.) *Compendium of Bean Diseases*. APS Press, Minnesota.

Hampton, J. G. and Tekrony, D. M. (1995). Handbook of Vigor Methods (3rd edition). The International Seed Testing Association, Zürich, 117 pp.

Holliday, P. (1980). *Fungus Diseases of Tropical Crops*. Cambridge University Press, Cambrgidge.

International Seed Testing Association [ISTA] (2007). International Rules for Seed Testing. Proceedings of International Seed Testing Association. ISTA, 8303 Bassersdorf, Switzerland.

La Grange, N. and Aveling, T. A. S. (1998). First report of *Alternaria cassaie* on cowpea. *Plant Disease* 82(10): 1171.

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

Latunde-Dada, A. O. (1990). Assessment of anthracnose disease in some cultivars of cowpea (*Vigna unguiculata* [L.] Walp.). *Journal of Phytopathology* 130: 147-156.

Maredia, M., Howard, J., Boughton, D., Naseen, A., Wanzala, M. and Kajisa, K. (1999). Increasing Seed System Efficiency in Africa: Concepts, strategies and issues. Michigan State University International Development Working Paper. Department of Agricultural Economics- MSU East Lansing Michigan, pp 12-13.

Maredia, M., and Howard, J. (1998). Facilitating seed sector transformation in Africa: Key findings from the literature. *FS II Policy Synthesis* No 33, USAID, Washington, and Michigan State University, East Lansing, USA.

Mathur, S. B. and Kongsdal O. (2003). Common Laboratory Seed Health Testing Methods for Detecting Fungi. Pub. International Seed Testing Association, 8303 Bassersdorf, CH-Switzerland.

Nutsuga, S. K., Vibeke, L., Atokple, I. D. K. and Ayensu, F. K. (2004). Seed-borne Mycoflora of Major Food Crops in Ghana. Journal of Science and Technology, Vol. 24 No. 2, 2004.

Onesirosan, P. T. and Barker, L. N. (1971). Stem anthracnose of cowpeas in Nigeria. *Plant Disease Reporter* 55: 820-822.

Partridge, J. E. (2008). *Fusarium* Stalk Rot. Department of Plant Pathology, University of Nebraska-Lincoln. *Journal of the National Collegiate Honours Council* -Volume 6, no. 2.

Pelmer, D. P. (2005). Agriculture in the developing world: connecting innovation in plant breeding research to downstream applications. *Proceedings of the National Academy of Sciences,* USA. *(PNAS)* 102 (44) 15739-15746.

Rawal, R. D. and Sohi, H. S. (1984). Assessment of losses in pod yield of cowpea due to *Septoria vignicola* Rao. *Indian J. Plant Pathol.* 2: 59-63.

Rohrbach, D. Minde I. and Howard J. (2004) Looking beyond national policies: regional harmonization of seed market. In Rohrbach D. and Howard J. eds Seed Trade Liberalization in Sub-Saharan Africa-Workshop Proceeding Dec. 5-6th, 2002 Pp 14-35 Matopos Research Station, Bulawayo, Zimbabwe. ICRISAT- Bulawayo Zimbabwe.

Rubyogo, J. C.; Sperling, L.; Nasirumbi, L. and Kasambala, S. (2007). Developing seed systems with and for the marginalized: case of common beans (*Phaseolus vulgaris* L.) in East, Central and Southern Africa.

Schwartz, H. F. (1989). Additional fungal pathogens. Pages 231-259 in: Schwartz, H.F. & Pastor- Corrales, M.A. (eds.) *Bean Production Problems in the Tropics 2*nd ed. Centro Internacional de Agricultura Tropical, Columbia.

Scowcroft, W. R. and Polak Scowcroft, C. E. (1998). Seed security: disaster response and strategic planning. In Proceedings: International Workshop on Seed Security for Food Security. pp 159-186. FAO, Rome and Accademia dei Georgofili, Florence, Italy.

Singh, B. B., Raj, D. R. M., Dashiel, K. E. and Jackai, L. E. N. (1997). Advances in cowpea research. Co-publication of International Institute of Tropical Agriculture

(IITA) and Japan International Research Centre for Agricultural Sciences. IITA, Ibadan, Nigeria, Devon. Pp 1-7.

Singh, S. R. and Allen, D. J. (1979). *Cowpea Pests and Diseases*. International Institute of Tropical Agriculture, Ibadan.

Smith, J. E. and Aveling, T. A. S. (1997). *Colletotrichum dematium*: Causal agent of a new cowpea stem disease in South Africa. *Plant Disease* 81: 832.

Tafesse, K. (1998). Towards seed industry development in Ethiopia. In Proceedings: International Workshop on Seed Security for Food Security. pp 201-206. FAO, Rome and Accademia dei Georgofili, Florence, Italy.

Tripp R., Walker D. J., 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 BrongAhafo and Volta Regions. NRI Bulletin.

Ullstrup, A. J. (1985). Plant Disease. *Rev. Phytopathol* 69:658-659.

USDA. (1960). Index of Plant Disease in the United States. Agricultural Hand Book. No. 165: 531 pp. USDA.

Walker, D. J., and Tripp, R. (1998). Seed management by small-scale farmers in Ghana and Zambia. In Proceedings: International Workshop on Seed Security for Food Security. pp207-215. FAO, Rome and Accademia dei Georgofili, Florence, Italy.

Williams, R. J. (1975). Diseases of cowpea (*Vigna unguiculata* (L.) Walp.) in Nigeria. *PANS* 21: 253-267.

Wobil, J. (1998). Seed security issues in southern Africa. In Proceedings: International Workshop on Seed Security for Food Security. pp 217-226. FAO, Rome and Academia dei Georgofili, Florence, Italy.

Wright, M. and Tyler, P. (1994). Traditional seed-saving practices in northern Ghana and central Malawi. NRI Report N2102 (S) ii + 50pp + annexes.

Wright, M., Delimini, L., Luhanga, J., Mushi, C. and Tsini, H. (1995). The quality of farmer saved seed in Ghana, Malawi and Tanzania. NRI Research Report.

8.0. Appendices

Appendix A: QUESTIONNAIRE FOR SEED SURVEY

1. Region/ Area/Zone: …………………………………………………………………….
2. Name of Town/Village: ……………………………………………………………….
3. Age of farmer: A. 18-29 ( ) B. 30-39 ( ) C. Above 40-50 ( ) D. Above 50 ( )
4. Sex: Male ( ) Female: ( ) 5. Educational Background:
    a. A. Primary ( ) B. Secondary ( ) C. Tertiary ( ) D. No Formal Education ( )
    b. How long have you been farming? A. 1-5 yrs ( ) B. 6-10yrs. ( ) C. Above 10 yrs. ( )
6. Size of farm (acres) for a season: Major ……………………… Minor…………………………..
7. How many times do you farm in a year? A. Once ( ) B. Twice ( ) C. Other (s)………………
8. When do you plant (Sowing to harvest time)? A. Major season ( ) B. Minor season( ) C. Both ( )
9. Type of farming. A. Isolation ( ) B. Mono/Sole ( ) C. Subsistence ( )
10. Cropping pattern. A. Rotation ( ) B. Bush fallow ( ) C. Continuous cropping ( )
11. Do you rogue your farm? A. Yes ( ) B. No ( )

SEED QUALITY ASSESSMENT

12. What seed do you use to plant? A. Foundation ( ) B. Certified ( ) C. Saved Seed ( ) 13. What is your source (s) of Seeds? A. GLDB ( ) B. Agro-store ( ) C. Saved ( ) D.Other(s)Specify

14. How do you store your seeds before planting/selling the following season?

A. Cold-room ( ) B. Open place ( ) C. Store room ( ) D. Others (specify):..…………………..

15. Do you treat your seed before storage? A. Yes ( ) B. No ( )

16. If yes, what do you use for seed treatment? A. Insecticide ( ) B. Fungicide ( ) C. Rodenticide ( )

17. Do you readily get enough seeds for your farm? A. Yes ( ) B. No ( )

18. If no, what do you do? ………………………………………………………………….

19. Do you test your seeds for germination potential before they are sown? Yes ( ) No ( )

20. If no, what do you do if some fail to germinate? ………………………………………

21. Do you treat your seeds before sowing? A. Yes ( ) B. No ( )

22. If yes, with what and against what? ……………………………………………………

23. If no, do you encounter any pest or disease problems?

    a. Before flowering: ……………………………………………………………………….

    b. Fruiting stage: ……………………………………………………………………..

24. How do you process your seed? A. Hand ( ) B. Machines ( ) C. Both ( )

25. How do you package your seeds? A. Poly-bag ( ) B. Paper bag ( ) C. Others..………………...

26. What is your estimated seed yield from the farm in a season (bags per acre)......…………………..

27. What is your market outlet? A. Local market ( ) B. Govt. ( ) C. Other(s),Specify………......

28. How long are you able to store? A. 0-6 months ( ) B. 7-12 months ( ) C. Above 12 months ( )

29. What is the cost of storage? A. High ( ) B. Average ( ) C. Low ( )

30. Any additional peculiar problem(s)…………………………………………………………

Appendix B: List of Respondents across the five agro-ecological zones of Ghana

Case	Region	Ecozone	District	Town	Farmer/Respondent
1	Upper West	Guinea Savannah	Wa	Pissi	Yireku
2	Upper West	Guinea Savannah	Wa	Pissi	Zinkane Sumpoa
3	Upper West	Guinea Savannah	Wa	Kunfabiala	Wabuzia
4	Upper West	Guinea Savannah	Wa	Kunfabiala	Dabiare
5	Upper West	Guinea Savannah	Wa	Bamahu	Fuseini Abdulai
6	Upper West	Guinea Savannah	Wa	Bamahu	Dramani Iddrisu
7	Upper West	Sudan Savannah	Sissala East	Walembelle	Giri Chokidei
8	Brong Ahafo	Transition	Nkoranza South	Ayerede	Osei Kofi
9	Upper West	Sudan Savannah	Sissala East	Walembelle	Amed Nebaradom
10	Upper West	Sudan Savannah	Sissala East	Sakai	Issaka Maani

Case	Region	Ecozone	District	Town	Farmers/Respondents
11	Upper West	Sudan Savannah	Sissala East	Sakai	Batong Dimah
12	Upper West	Sudan Savannah	Sissala East	Tumu	Dramani Taeli
13	Upper West	Sudan Savannah	Sissala East	Tumu	Taedu Dentieboko
14	Upper East	Sudan Savannah	Kassena Nankana	Navrongo	Christopher Ayiwo
15	Upper East	Sudan Savannah	Kassena Nankana	Navrongo	Patrick Aluah
16	Upper East	Sudan Savannah	Talansi Nabdam	Pwalugu	Teni Tia
17	Upper East	Sudan Savannah	Talansi Nabdam	Pwalugu	Sulemana Ayine
18	Upper East	Sudan Savannah	Bolgatanga	Zuarungu	Abubakar Yakubu
19	Upper East	Sudan Savannah	Bolgatanga	Zuarungu	Florence Asabuko
20	Upper East	Sudan Savannah	Bolgatanga	Sokabisi	Mark Anaaya
21	Upper East	Sudan Savannah	Bolgatanga	Sherigu	John Akolga
22	Northern	Guinea Savannah	Savelugu Nanton	Kanshegu	Mashud Rufai
23	Northern	Guinea Savannah	Savelugu Nanton	Kanshegu	Abdulai Abubakar
24	Northern	Guinea Savannah	Savelugu Nanton	Yiworgu	Seidu Abubakar
25	Northern	Guinea Savannah	Savelugu Nanton	Yiworgu	Abubakar Wumbi
26	Northern	Guinea Savannah	Tamale	Nyeshei	Abdulsomed Abdulai
27	Northern	Guinea Savannah	Tamale	Nyeshei	Hamza Fuseini
28	Northern	Guinea Savannah	Tamale	Dufaa	Abdulraman Yakubu
29	Northern	Guinea Savannah	Tamale	Dufaa	Alhassan Yakubu
30	Northern	Guinea Savannah	Tamale	Lahagu	Abdul Mumin Dawda
31	Northern	Guinea Savannah	Tamale	Lahagu	Mahamedu Dawda
32	Brong Ahafo	Transition	Tano North	Terchire	Agartha Serwaa
33	Brong Ahafo	Transition	Tano North	Terchire	John Kwarkye
34	Brong Ahafo	Transition	Techiman	Techiman	Owusu Brempong
35	Brong Ahafo	Transition	Techiman	Techiman	Ahmed Sulemana
36	Brong Ahafo	Transition	Techiman	Kuntunso	Ajalatu Osman
37	Brong Ahafo	Transition	Techiman	Hansua	Emmanuel Gandah
38	Brong Ahafo	Transition	Techiman	Tanoso	Morro Issah
39	Brong Ahafo	Transition	Techiman	Tanoso	Stephen Safo
40	Brong Ahafo	Transition	Nkoranza South	Nkoranza	Ernest James Kofie
41	Brong Ahafo	Transition	Nkoranza South	Nkoranza	Datuah Philip
42	Brong Ahafo	Transition	Nkoranza South	Donkronkwanta	Atuluke Apokola
43	Brong Ahafo	Transition	Nkoranza South	Donkronkwanta	Adusi Poku
44	Greater Accra	Coastal Savannah	Ga West	Onyansana	Fuseini Afadekpe
45	Greater Accra	Coastal Savannah	Ga West	Onyansana	Ali Dzodzowu
46	Greater Accra	Coastal Savannah	Ga West	Samsamotaomina	Frederick Aryee

47	Greater Accra	Coastal Savannah	Ga West	Samsamotaomina	Yao Gborglo
48	Greater Accra	Coastal Savannah	Ga West	Mayeraokuleman	Joseph Amoo Djan
49	Greater Accra	Coastal Savannah	Ga West	Mayeraokuleman	Daniel Oko Sanka
50	Greater Accra	Coastal Savannah	Ga West	Mayeraokuleman	Samuel Quaye
51	Central	Coastal Savannah	Awutu Efutu Senya	Winneba	S. K. Owusu
52	Volta	Forest	Hohoe	Gbi Godenu	Valeria Dede
53	Greater Accra	Coastal Savannah	Dangbe West	Ayikuma	Naomi Adamteng
54	Greater Accra	Coastal Savannah	Dangbe West	Ayikuma	Christian Adasu
55	Greater Accra	Coastal Savannah	Dangbe West	Agormeda	Andrews Teikuteye
56	Greater Accra	Coastal Savannah	Dangbe West	Agormeda	Enoch Teye
57	Brong Ahafo	Transition	Tano North	Duayawnkwanta	John Kumi
58	Volta	Forest	Hohoe	Hohoe	Atsutse
59	Volta	Forest	Hohoe	Hohoe	Frank Ntim
60	Volta	Forest	Hohoe	Gbi Godenu	Christian Okae
61	Volta	Forest	Hohoe	Ve Koloenu	Owusu Fredrick
62	Volta	Forest	Hohoe	Ve Koloenu	William Ntem
63	Brong Ahafo	Transition	Nkoranza South	Ayerede	Kofi Bio
64	Brong Ahafo	Transition	Nkoranza South	Grumakrom	James Konlan
65	Brong Ahafo	Transition	Nkoranza South	Grumakrom	Awuni Konlan
66	Ashanti	Forest	Ejura Sekyedumase	Drobong	Adjei Boateng
67	Ashanti	Forest	Ejura Sekyedumase	Drobong	Collins Owusu
68	Ashanti	Forest	Ejura Sekyedumase	Nkranpo	Adu Alexander
69	Ashanti	Forest	Ejura Sekyedumase	Nkranpo	George Nsiah
70	Ashanti	Forest	Ejura Sekyedumase	Sekyidumase	Adubofour Frank
71	Ashanti	Forest	Ejura Sekyedumase	Sekyidumase	Isaac Yeboah
72	Eastern	Forest	Fanteakwa	Otuater	Kumi Samuel
73	Eastern	Forest	Fanteakwa	Otuater	Teye Kojo Samuel
74	Eastern	Forest	Fanteakwa	Ahomahomaso	Mensah Christian
75	Eastern	Forest	Fanteakwa	Ahomahomaso	Ekutor Maxwell
Case	**Region**	**Ecozone**	**District**	**Town**	**Farmers/Respondents**
76	Eastern	Forest	Fanteakwa	Abuorso	Nuru Alhassan
77	Brong Ahafo	Transition	Tano North	Duayawnkwanta	David Tetteh
78	Eastern	Forest	Fanteakwa	Abuorso	Asare Acheampong
79	Northern	Guinea Savannah	Savelugu Nanton	Savelugu	Agolgo Nuhu
80	Northern	Guinea Savannah	Savelugu Nanton	Savelugu	Abdul Zakari
81	Central	Coastal Savannah	Awutu Efutu Senya	Winneba	Ernest Ahianyo
82	Central	Coastal Savannah	Awutu Efutu Senya	Abasa	Emmanuel Owusu
83	Central	Coastal Savannah	Awutu Efutu Senya	Abasa	Kyei

84	Central	Coastal Savannah	Awutu Efutu Senya	Awonbrew	Botwe
85	Central	Coastal Savannah	Awutu Efutu Senya	Awonbrew	Emmanuel Akuna
86	Central	Coastal Savannah	Awutu Efutu Senya	Otsew	Bart Addision
87	Upper East	Sudan Savannah	Kassena Nankana	Namolo	Gwiri Osmanu
88	Upper East	Sudan Savannah	Kassena Nankana	Namolo	Mumuni Aftii
89	Upper East	Sudan Savannah	Talansi Nabdam	Yirango	Dramani Munin
90	Upper East	Sudan Savannah	Talansi Nabdam	Yirango	Amadu Seidu