SEED MAIZE (***Zea mays L.***) QUALITY FACTORS FROM FIVE AGROECOLOGICAL ZONES IN GHANA AND THEIR IMPACT ON GROWTH AND GRAIN YIELD

BY

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Declaration

I hereby declare that this submission is my own work towards the MPhil and that, to the best of my knowledge, it contains no materials previously published by any person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

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ABSTRACT

Maize (*Zea mays L.*) is a staple cereal food crop and is cultivated in different agro-ecological zones of Ghana. However, its yield is very low compared to the crop potential. There are constraints on yield, out of which uncertified and low-quality seeds is the most important one. Seed quality evaluations of maize seeds produced under certified and farmer-saved seed systems from five agro-ecological zones of Ghana have been done in 2015 minor season. Seed purity analysis and fungus identifications were conducted in the Pathology lab, Department of Crop and Soil sciences using randomized complete design in three replications. 1000g of working maizseed samples was also taken from submitted samples and then sorted into pure, broken, discoloured, shriveled, and pets damaged seeds by visual examination. The components were weighed using an electronic weighing balance. Four hundred maize seeds were selected from pure seed samples under both seed systems and planted on trays filled with moistened sterilized river sand in a randomized complete design with four replications at the plant house. After seven days seedlings were counted and sorted out into normal, abnormal seedlings, ungerminated, and dead seeds. Ten seeds were selected randomly from pure seed samples and socked in distilled water for 24h and then separated in to endosperm, cotyledon, and embryo. The components were plated on Petridishes half-filled with PDA and after seven days fungi identifications were done using a compound microscope and the help of identification manual (Hunter and Barnett, 1978). Data on seed purity analysis, germination tests, and fungus infection were collected. Field trial was done after the land was slashed by cutlass, ploughed and harrowed. The experiment was done 2x5 factorial randomized complete block design with four replications at the spacing of 80x40 cm with three seeds per hill one seedling thinned later two weeks after planting. Data on seedling emergence, number of plants per m^2, measurements of plant height at 20, 40, 60, 80, 100 days after planting, days to silk, days to tassel, maturity date, and yields were collected. The data were analyzed by Genstat statistical package software (ver. 12) and means were separated by least significant difference at 5%. The laboratory purity analysis results showed that, seeds from certified seed system gave higher percent value than farmer-saved seed system. Coastal Savannah 95.10%, Semi-deciduous 94.57%, Transitional 94.53%, Guinea Savannah 94.13%, and Rainforest zones 93.73% respectively. In addition the germination tests were showed that, certified seed system was recorded the highest normal seedlings across the study zones. The maximum mean yield was from certified seed from the

Guinea Savanna zone (664kg/ha) and the minimum value was observed in farmer-saved seed from the Transitional zone (390.5kg/ha). The study realized that seed quality parameters have an impact on emergence, growth, and grain yields of maize.

To maintain optimal plant population and increase maize yield, certified seeds should be available to the farmers. And also strengthen farmers' capacity in seed production and postharvest handling of the seeds. However, further study of the variety across different locations and under farmer conditions are recommended.

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Abbreviations and acronyms

SSA	Sub-Saharan Africa
OPVS	Open pollinated varieties
MoFA	Ministry of Agriculture
CRI	Crops Research Institute
GGDP	Ghana Grain Development Project
FAO	Food and Agriculture Organization
NGOS	Non-Governmental Organization
PDA	Potato Dextrose Agar
NPK	Nitrogen, Phosphorus and Potassium
DAP	Days after planting
PG	Plant girth
SE	Seed emergence
DT	Days to tassel
DS	Days to silk
DPM	Days of plant maturity
TPDWT	Total plant dry weight
Y/ha	Yields per hectare

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays L.*) is a cereal crop used in human diet in many parts of the world including Ghana. Maize is the second largest produced crop in Ghana next to cocoa. It is grown in diverse environments by variable seasonal rainfall ((Zhao *et al.*, 2014). Maize is cultivated in five Agroecological zones of Ghana, namely Transitional, Guinea, Coastal Savannah, Semi-deciduous, and Rainforest zones (Asare *et al.*, 2012). The maize kernel is composed of 75% starch, 10% protein, 4% lipid, 3% sugar and 4% ash (Ranum *et al.*, 2014). However, the yield remains very low when compared to the potential of the crop (Klutse *et al.*, 2013). Most countries in Africa still mainly depend on farmer-saved seeds in which, about 80-90% of seeds come from the farmer-saved seeds, even though improved, superior varieties have been developed in most of those countries (Scoones and Thompson, 2011). An estimated 85-90% of the total seed maize used by Ghanaian farmers are produced by farmers themselves on on-farm seed production. However, this system of seed production appears to neglect some quality aspects (McGuire and Sperling, 2015). The limitations of this old way of producing seeds are low yield and lack of guaranteed seed quality leading to dropping of desirable traits (Tsinigo, 2014). More than 95% of maize producers in Ghana are aware of certified seed, but only 27% of them used certified seeds to produce maize (Ragasa *et al.*, 2013). Seeds of the newly developed varieties are not usually available in adequate quantities due to the limitation of certified seed production and environmental stress problems (Awotide *et al.*, 2013). These are the reasons why the majority of smallholder farmers still rely on unimproved, open-pollinated varieties (OPVs) for their plantings. The yield of the crop is low, with an average of approximately 1.5 t/ha compared to the potential yield of 5.5 t/ha (Tittonell and Giller, 2013). Low seed quality and unimproved technologies are the major reasons for this yield gap. Farmer's expectations can only be achieved if the seed is true to the selected variety and high-quality.

Use of quality seed can produce yield through the high and quick emergence of seedlings, foremost to the production of vigorous plants and best stand formation under a wide range of environmental conditions. Increasing productivity of any crop is determined by the seed quality (Hossain, 2014). Crop seed contains all the genetic information that determines yield potential, adaptation to environmental situations, and resistance to insect pest and disease. The availability of inputs for seed production, pest and disease pressures are significant limitations for farmers in producing quality seeds. Seed quality is the sum of multiple components of cultivar purity, analytical purity, germination, seed vigour, seed health, and moisture content. Good seed storage is a basic prerequisite in seed production (Anandalakshmi *et al.*, 2015). Because of the amount of money involved and the cost of sustaining desirable seed storage facilities, many seed lots are stored under unfavorable conditions and that can expose the seeds to storage pests and diseases which can reduce the physical feature of the seeds.

Several reports indicated that the farmer-saved seeds do not fulfill seed quality requirements. However, limited research work has been done on maize seed quality and its effect on grain yield. Therefore, using good quality seeds can increase the yield potential of a crop and thus, it is the most important input to the agricultural development of developing countries such as Ghana (Mehta *et al.*, 2015) Thus, to achieve this objective, good and uniform field seedling establishment are necessary. The two main seed supply systems in Ghana are formal and informal seed or certified and farmer-saved seed production systems. The farmer-saved seeds system is unstructured and its activities are not supervised by any public institution. In this system, farmers save seeds of locally produced crops and varieties from their fields for their own use. They also exchange seeds during the succeeding cropping season. Farmer-saved seeds constitute about 90% of maize seeds sown annually in Ghana. They are usually high in quantity supply but low in quality (Hellin *et al.*, 2011). The informal system is producing seeds by traditional agricultural methods as producing grains, and sometimes also they are seeds saved by selecting from the previously harvested grain crops. Farmers do not follow scientific seed production techniques because they have constraints such as accessible seed production inputs such as basic seeds, fertilizers, agrochemicals, farm machinery and storage facilities (Lambert *et al.*, 2016). Seed produced by this system is not inspected and certified.

The formal seed sector is organized with the major goal to diffuse quality seed of improved varieties developed by the formal breeding programmes by producing basic and certified seeds. The regulation present in this scheme is strong to preserve variety identity and purity as well as guarantee physical, physiological and sanitary quality of the seeds. The main objective of this study was to evaluate the impact of seed quality on germination, emergence, growth and yield of maize.

The specific objectives were to:

I. determine maize seed quality differences between farmer-saved and certified maize seeds

II. determine maize seed quality differences from the various agro-ecological zone in Ghana, and

III. evaluate maize seed quality differences and their impact on growth parameters and yield of maize.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Economic importance of maize

Maize is a widely cultivated cereal crop in Ghana and is grown under diverse agro-ecologies under rain-fed production. The maize kernel is composed of 75% starch, 10% protein, 5% lipid, 3% sugar and 4% ash (Ranum *et al.*, 2014). In Ghana, maize is the base for several traditional food preparations such as banku, kenkey and tuozafi (Zalabák *et al.*, 2014) Maize is the first crop in terms of area planted among cereal crops, and accounts for 55-60% of total cereal production (Avukpor, 2015). Additionally, maize is the largest commodity crop in Ghana next to cocoa. The total average annual maize production from 2007-2012 was 1.5 million metric tons, which indicates that maize production in Ghana has been increasing over the past few years (Alexandratos and Bruinsma, 2012). The agricultural sector provides about 60% of export earnings and economically supports 80% of the total population through farming in Ghana (Killick, 2010). However, around 70% of maize production is done by smallholder farmers under rain-feed conditions (Ragasa *et al.*, 2014). Maize produced in the Rainforest, Transitional and Guinea Savannah zones contributed about 64.1% (Addai, 2011). However, the production relied on traditional farming methods and low-quality seeds. The use of superior certified seeds for planting is 10% (Baffour Badu-Apraku *et al.*, 2014).

2.2 Maize producing agro-ecologies in Ghana

(A) Coastal Savannah zone. The coastal Savannah zone (Figure 1) contains a thin belt of Savannah that runs along the coast, spreading to the east of the country. Farmers in this zone grow maize and cassava, often intercropped, as their principal staples. Annual rainfall, which is bimodally, distributed, totals 800 mm, so most maize is planted following the start of the main rains that begin in March or April. The tropical soils are generally light in texture and low in fertility, so output is low. Research reports that higher maize productivity have been achieved in the Savannah zone than in the Rainforest zone which has traditionally been regarded as the major production area for maize crop (Breisinger *et al.*, 2011).

(B) Rainforest zone. Most of Ghana's forest is semi-deciduous, with only a small proportion of high rain forest in the south-western part of the country. Maize in the Rain forest zone is grown in dispersed plots, usually intercropped with cassava, plantain, and/or cocoyam as part of a bush fallow system (Adjei-Nsiah *et al.,* 2012). Although some maize is consumed in the Rain forest zone, it is not a foremost food staple and much of the crop is sold. Yearly rainfall in the zone averages about 2200 mm (Morris, 2007). Maize is planted both in the major rainy season (beginning in March) and in the minor rainy season (beginning in September) in the Rainforest.

(C) Transition zone. The Transition zone is an important region for commercial maize seed production. Much of the Transition zone has deep, friable soils and moderately sparse tree cover (Attua and Pabi, 2013). Rainfall is bi-modally distributed and averages about 1,300 mm per year. Maize in the transition zone is sown in both the main and minor seasons, usually as a mono-crop or in association with yam and/or cassava.

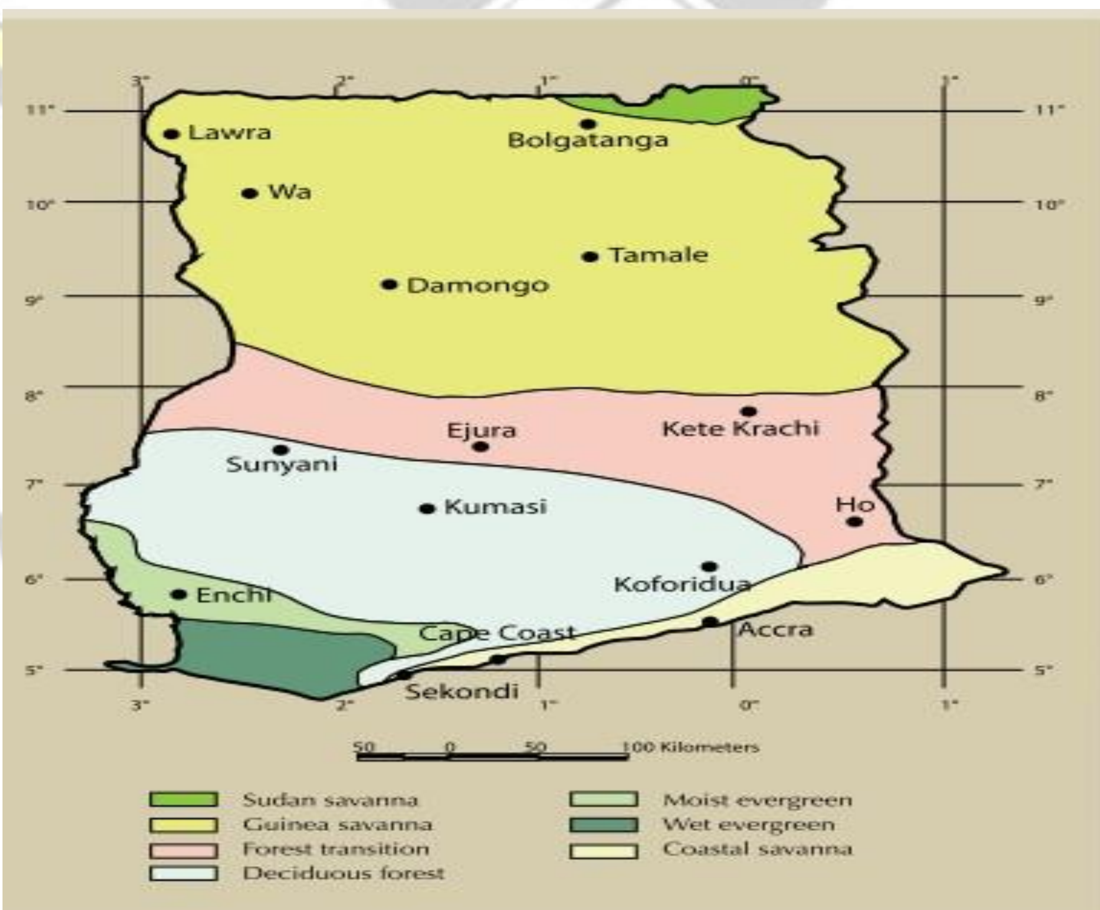

Figure 2.1. Agro-ecological zones of Ghana

(D) Guinea Savannah zone. The Guinea Savannah zone occupies most of the northern part of the country. Yearly rainfall totals about 1000 mm, falling in a single rainy season beginning in April or May. Sorghum and millet are the dominant cereals in the Guinea Savannah, however, maize grown in association with small grains, groundnut, and/or cowpea is also important. Maize is grown in continuously cultivated fields found close to farmhouses, as well as in more distant plots under shifting cultivation (Akudugu *et al.*, 2012).

(E) Semi-deciduous Forest Zone. The zone has dual maxima rainfall in a year, with peaks in May/June and October. Average annual rainfall is 1500 mm. Humidity is high averaging about 85% in the southern districts and 65% in the northern part of the region (Asante *et al.*, 2011). The maize productivity gap between stressed and high potential areas is not only an issue of technology but also differences in climatic factors.

2.3 Seed maize production in Ghana

Improving the quality of seed of maize varieties in Ghana is important for agricultural productivity (Louwaars and de Boef, 2012). The main duty of seed science is production of quality seeds with good physiological, biochemical, and healthier properties. National and international research centers often provide the breeder or foundation seeds for the industry, but insufficient production of source seeds are a major constraint in sub-Saharan Africa including Ghana. Currently seed production is an important factor in the process of meeting the growing demand for sufficient quantities of healthy and safe food (Kumar and Siddharthan, 2013). The Crops Research Institute (CRI) of Ghana and universities have been responsible for the development of improved maize varieties (Lyon and Afikorah-Danquah, 1998). Maize is the single crop with the largest area planted with an average of 651,567 ha in Ghana (Heisey and Mwangi, 1996). However, from these areas, 10.8% are covered by certified seed, while the rest was planted with farmer-saved Obatanpa variety. This maize variety was released in 1992, since then the variety has become more popular and dominant even if the new varieties come on the market. Nearly 95% of the certified seeds produced in Ghana between 2001 and 2011 were the Obatanpa variety (Ragasa *et al.*, 2014). Fungal infection and insect infestation are the main factors that reduce the quality of seed produced in the country, especially the informal seed systems, because they do not follow scientific seed production principles and appropriate storage facilities are not used. Seeds that are stored well and protected have high germination capacity (Sadia, 2012).

The Ghana Seed Company, a government institution was responsible for certified seed production in Ghana. The seed company was lacked funds and trained personnel, therefore, unsuccessful to achieve its goals (Ceccarelli and Grando, 2007). Therefore, improved maize seed continued to be unavailable to many farmers to satisfy demand for improved seed. The Ghana grain development Project management, in consultation with research institutions, decided to focus on developing open-pollinated varieties (OPVs) rather than hybrids. One advantage of OPVs compared to hybrids is that farmers who grow OPVs can save seed from their own harvest for growing the next season. In disparity, farmers who grow hybrids must buy fresh seed every cropping season.

2.4 Seed Quality Attributes

2.4.1 Physical qualities of the seed in the seed lots

Depending upon severity of damage by factors such as weather, mechanical and size of the seeds can have negative impact on germinations (Righetti *et al.*, 2015). The important components of seed quality are seed vigour, seed health and moisture content (Hampton, 2002). Physical quality parameters such as seed homogeneity, the level of unwanted material in the seed and discoloured seed can be identified by visually examining seed samples. Damaged seed (broken, cracked or shriveled) seed may not germinate and is more likely to be attacked by storage pests or microorganisms (Setimela *et al.*, 2016). Good quality seed should be free of those mentioned quality parameters above.

According to Aydinsakir *et al.* (2013) techniques of collecting, aeration of the cobs, shelling the seeds, seed processing and seed storing are the critical periods in the production of quality seeds. Full-sized grains, free from physical damage and pests and disease should be carefully chosen for seed. The process of selection begins in the field previous to harvest with identification of fullymature, vigorous, healthy plants from which to take the seeds. Any damaged, diseased, pestinfested and off-type seeds (different variety) should be removed. Drying should be done on the cob, before threshing, since threshing is not possible at high moisture content levels (Powell, 2009).

Seed ranks high in plant production and, therefore, confirming its quality is the import of present seed science and a precondition for attaining high yields. For that reason, it is essential to have reliable techniques and checks for use in seed quality and vigour testing (Milošević *et al.*, 2010).

Growers believe high quality, genetically unadulterated seed, are a result seed companies' quality control program than screening of seeds from harvested. According to Zewdie Bishaw *et al.* (2012) and Z Bishaw *et al.* (1997) genetically enhanced varieties and their distribution through better seeds systems have been critical contributors to yield increases.

2.4.2 Physiological qualities of seeds

The capacity to germinate and grow satisfactorily in to a normal plant is the most important quality desired of a seed (Copeland and McDonald, 2012). The germination percentage shows the ability of seed to develop from the soil to produce a plant in the field under normal circumstances. Seed vigour is the capability of seed to emerge from the soil and survive under possible stresses in field situations and to grow quickly under adequate situations (Finch-Savage and Bassel, 2015). The vigour of seeds at the period of storage is an essential aspect that affects their storage period. Seed can only achieve its biological role if it is of good quality. Therefore, physically uniform seed of an improved variety will be useless if it is low in germination and vigour. Information concerning both the necessities of preserving seed viability and methods of providing appropriate storage conditions is increasing (Anandalakshmi *et al.*, 2015). Starting with harvest, seed lots usually pass through a series of procedures. These include harvesting, drying, shelling, cleaning, grading, transporting and storing. There is high capital investment and cost of maintaining desirable seed storage facilities, therefore, many seed lots are stored under unfavorable conditions and that can expose the seeds to storage pests and diseases which can decrease the physiological aspect of the seeds. Seeds may have internal fractures from impaction, moisture stress, or heat stress without reliable damage to the surface (Lee *et al.*, 2013). Appropriate storage is required for all common crop seeds at appropriate moisture content and temperatures during storage. Even though maize seed can be stored for a considerable period of time, preservation of quality during long-time storage is a problem in many parts of the world (Kauth and Biber, 2015). Storage pests are major constraints in maize seed, with losses of about,

30%. Farmers in Africa are deserting traditional storage structures: they shell their maize earlier and store the grain in polypropylene bags. However, damages due to insects while in storage are high.

Seed quality is affected by conditions during storage, resulting in physicochemical changes in especially amylase and starch content that lead to significant qualitative and quantitative losses. According to Wang (2015) seed stored in low-temperature storage maintained high seed quality. All the storage variables (moisture content, temperature and time of storage) have substantial result on growth. Therefore, to maintain seed quality, Maize seed should be stored under low storage temperature. Below 18^{o}C has been found to be effective (MacRobert *et al.*, 2014).

2.4.3 The genetic quality of seeds

A mixture of varieties can be a problem because: mixed varieties may mature at dissimilar periods which lead to problems in harvesting, post-harvest handling and consequences in poorer yields (Kanampiu *et al.*, 2003). Additionally, each seed of an undesired variety in a mixture will produce seed when it is planted and those seeds will produce extra seed so that each year the amount of the undesired variety increases (Aidoo *et al.*, 2014a.

2.4.4 Seed pathological quality parameters

To set up a healthy field that will give a good yield, healthy seeds are needed because seed-borne pathogens bring about poor germination, poor vigour, poor crop establishment and crop stands (Tinivella *et al.*, 2009). Another reason for reduced seed quality is disease, which attack the seeds either in the field previously harvest or while in storage. The health of seeds refers typically to the existence or nonappearance of disease-causing organisms, such as fungi, bacteria and virus in the seeds. However, worsening of stored seeds by fungi is controlled mainly by drying the seeds to safe moisture content prior to storage in a dry place. Storage fungi cannot attack seeds that are in moisture equilibrium with 65% relative humidity or lower (Ghangaokar and Kshirsagar, 2013). The moisture content of a seed lot represents the average of many seeds, so some specific seeds may possibly contain the unsafe amount of moisture even though the moisture content of the lot may be at a safe level. Seeds having too much moisture are susceptible storage fungi, which may then spread through the lot. Therefore, it is very important to precisely measure seed moisture content. For best results, seeds should be dried as soon as possible after harvest, and then carefully cleaned prior to storage in an environment where they will not imbibe moisture (Baffour Badu-Apraku *et al.*, 2014). Seed health testing is now obligatory in seed accreditation, because it can help to avoid the introduction of undesirable seed-borne and seed-transmitted disease pathogens into areas where they may not be present, particularly in the worldwide seed trade (Dechet *et al.*, 2014). It has, hence, become a mandatory crop care assurance test that some countries request before buying seeds on the international market. From those pathogens, fungi cause severe diseases on a broad range of crop plants, leading to significant economic losses. Pathogens might be transferred from the seed to the seedling causing disease symptoms and possible yield loss at a later age of growing. Some seed-borne diseases can grow quickly from one generation to the next and seed crops can also become infested from adjacent diseased crops. In this way, the seed-borne disease can affect the value of both certified and farmer-saved seed (Bisen *et al.*, 2015). The significance of seed contamination by pathogens is that they can cause reduction of crop yield, low germination and vigour, development of plant diseases, discoloration, shriveling, biochemical changes and alteration in physical properties of seeds.

Aspergillus and *Colletotricum* species are dominant seed fungi species in Ghana (Vismer *et al.*, 2015). *Aspergillus* species are present in the soil and contaminate a wide variety of agricultural crops in the field, storage areas, processing plants and during distribution (Perrone *et al.*, 2007).

2.5 Impacts of storage conditions on seed quality

The purpose of seed storage is to maintain high seed germination and vigour from harvest to next planting period. Seeds are practically worthless if they fail to give adequate plant stands as well as healthy and vigorous plants. Good seed storage is, therefore, a basic requirement in seed production. The period between harvesting and cleaning seeds is very important. During this time, seeds still have high moisture content and seed deterioration can be fast through this period if moisture content is above 13% (Dubale *et al.*, 2014) . At moisture content beyond 13%, moulds may grow on the seed and heating could happen (Schmidt, 2015).

It is, therefore, necessary to take utmost care in the handling of seed after harvest. If at harvesting seeds is above 13% moisture content, arrangements for drying and aeration of seeds are important to preserve seed quality (Roberts, 2012). It is customary for seeds men and others interested in storage of seeds, to give primary attention to rooms or buildings considered as seed storage. Seeds aging and lose germination during storage cannot be stopped, but it could be reduced by providing the right storage conditions. Seed is important because there are large variations from one area to another with regards to mean temperature and relative humidity data from different months combined (Nguyen *et al.*, 2015). Therefore, it is important to know these differences in planning the seed storage needs in different areas.

2.6 Seed systems in Ghana

Better-quality seeds can have a considerable impact in agricultural productivity in the west and central African countries (B Badu-Apraku *et al.*, 2012). Seeds are one of the most essential bases of originality, mainly for resource-constrained smallholder farmers. Seeds transfer the genetic potential of the crops, defining the higher edge on yield and, therefore, the critical productivity of other inputs. The seed sector development in Africa varies considerably among countries. Active and varied seed industries have gradually emerged and are working in a few countries. In a number of other countries (e.g. Malawi and Zambia) the seed production and supply system have been established practically well in some areas for some crops. However, in most countries (e.g. Cameroon, Nigeria and Ghana) advancement has been very restricted in spite of investments and assistance (Lanteri and Quagliotti, 1997).

Seed supply is the basic important agricultural input, which is the foundation to increase agricultural productivity since they answer to farmers needs for both their growing productivity and crop uses (Sackey, 2010). Two types of seed systems exist in Ghana, a formal system established by the state and its technical partners, and an outdated or informal system based on a tradition of exchanges and shared support among producers (Niangado, 2010). Over 80% of smallholder farmers in Africa mainly get their seeds from the informal seed system which include farmers' own saved seeds, seed exchanges between farmers and finally buying from the local grain or seed markets (Etwire *et al.*, 2013).

2.6.1 Formal seed system

The certified seed system is characterized by a perfect sequence of activities (Jones, 2015). Regulations exist in this system to maintain variety uniqueness and cleanliness as well as to guarantee physical, physiological and sanitary quality, And seed selling takings place through officially approved seed outlets. The dominant idea of the formal systems is that there is a clear division between seed and grain. Seeds from the formal sector must drive quality control checks including the checking of purity, germination and quantity of inert matter present in the seeds. The percentage germination at the time of sale is typically showed on the seed bag. Formal systems are especially important when the seed is used to grow crops for commercial purposes and the sameness and high qualities of the product have to be stable. The formal sector consists of three systems (Louwaars and de Boef, 2012). The first, the mixed seed system, is possibly the most organized and planned of the systems, with various operatives in the seed value chain. The seed is formally qualified and varieties are enhanced. Stakeholders within this seed system include plant breeders in public research institutes involved in crop improvement and the production of breeder seeds, the Grain and Legumes Development Board, Ghana that produce basic seed and also private seed producers that produce certified seed. The Seed Inspectorate Division of the Ministry of Food and Agriculture accountable for seed accreditation and quality declaration and the private agro-input dealers are very critical in the selling of certified seed of better-quality. The second system, the public/quasi-public seed system, includes some public institutions that produce seed and planting materials of improved varieties for cash such as yam and cassava well as food crops. In the third system, the private, commercial seed system and commercial seed companies are either directly involved in the production or in the import of seed of high-value food and cash crops, which are subsequently marketed through agro-input dealers and their own networks (Aidoo *et al.*, 2014b).

The formal seed sector comprises of state, provincial and international agricultural research, private sector companies and business associations. This supply chain generally consists of the Public research institution, private seed production, seed quality regulators and seed marketing agencies. The public sector focuses on providing seed varieties of the major food crops, usually to farmers situated in favourable and accessible areas. The private sector focuses on hybrids, which are gainful but of inadequate relevance to small-scale farmers, mainly in less favorable areas. Thus, small-scale farmers in low-potential and remote areas have merely limited access to improved varieties and quality seed. According to (Tripp and Mensah-Bonsu, 2013), formal seed sector covered only up to 10% of seed needs of the farmers in Ghana.

2.6.2 Informal seed system

Farmer-saved seed system is amorphous and unregulated hence its activities are not monitored by any public institutions (Louwaars and de Boef, 2012). In the first seed system, farmers saved seed of locally important crops and varieties from their fields for their own use. They also exchange and barter seed during the next cropping season. The second system, the communitybased seed system, focuses on locally important food and cash crops. NGOs are vigorously involved in supportive societies in northern Ghana with the aim of enhancing food security. This system operates in an intermediate manner, as it includes both local and improved varieties, but does not involve any formal seed quality procedures. The third system, also an intermediary seed system, refers to local seed businesses, where farmers multiply and sell small quantities of quality seed of improved varieties to other farmers (Aidoo *et al.*, 2014a) and no authorized quality control is in place. This system includes major food crops, as well as vegetables and perennial fruit crops.

Seed-related activities tend to be collective and nearby organized, and the informal system holds most of the other ways in which farmers produce, distribute and obtain seed directly from their own-harvest, through barter among families, neighbors, and relatives and through local grain markets. In developing countries, the majority of farmers mainly get their seeds from farm-saved seed growers to exchange seeds among farmers (Bøhn *et al.*, 2013). The informal system tends to generate and maintain less uniform materials adapted to local requirements (landraces) but also may provide a network for the exchange of materials derived from improved varieties. It is characterized by all manner of seeds that the farmer can lay hands on at planting time and these can be from on-farm source. Informal seed sector refers to the collective efforts of farmers and their local communities, who save their own harvested seed for future planting, exchange seed within their communities or sell seeds in the local market. This type of chain is characterized by a seasonal crop production cycle linking production, selection of desirable types, harvesting, cleaning and storing their own seed, exchange of seed between family members and friends, trade or barter in the local market (Aw-Hassan *et al.*, 2008). Informal seed source system has its origins in the age-old tradition used by farmers that supply more than 90% of seed crops to meet their demands (Leclerc *et al.*, 2014). However, seed supply at this level can be very vulnerable to disaster and meet the gap between demand and supply seed delivery. Women have played essential role in supporting the informal seed sector, and more widely, in satisfying food security (Sackey, 2014).

CHAPTER THREE

3.0 MATERIALS AND METHODS

This investigation evaluated physical and physiological seed quality components of 15 seed maize samples collected from certified seed producers of Obatanpa maize variety from five agroecological zones in Ghana, and also 15 samples of farmer-saved maize seeds of the same variety from the same agro-ecological zones collected from 12-30th June, 2015.

Table 3.1 Seed samples collection points from five agro-ecological zones of Ghana.

Seed collection points/zone					
Seed types	Transitional	Guinea Savannah	Coastal Savannah	Semideciduous	Rain forest
Certified seeds	Bosunya	Adoe	Ajumako	Asuoyeboa	Prestea
	Timiabu	Tindoma	Bisease	Fumesua	Takoridi
	Ejura	Salamana	Enyan	Kokoben	Sekondi
Farmer-saved seeds	Subinso	Tindoma	Bisease	Kubeasse	Prestea
	Ejura	Gurungu	Ajumko	Kwadaso	Takoridi
	Bosunya	Salamana	Enyan	Fumesua	Sekondi

The five ecological zones are Transitional, Guinea Savannah, Semi-deciduous, Coastal Savannah and Rainforest zones (Table 3.1). From each ecological zone, three locations (towns and villages) known for the production of maize (Table 3.1) were included and from each one location three to six farmers were selected and seeds were collected from each. The seed samples were collected after the seeds had been harvested and processed in the same season as of certified seed and farmer-saved seeds. In each zone, three samples of Obatanpa maize seeds from certified seeds of one kilogram each and the same amount of samples from farmer-saved Obatanpa maize seeds were taken. Each of the seed samples was labeled as follows, name of the farmer, ecological zone, location, seed type and date of collection. The research was in two parts; laboratory work and field trial yield test. Seed purity analysis and health tests were conducted at the Plant Pathology Laboratory of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

3.1 Laboratory work

3.1.1 Determination of seed moisture content of maize seed samples

The moisture content of collected maize samples was determined using JOHN DEERE (Deere E Company, USA) electronic moisture tester obtained from the Insect laboratory, Department of Crop and Soil sciences, KNUST, Kumasi. Twenty grammes (20g) of maize seeds from each sample was weighed and poured carefully in to the moisture tester cup the moisture content recorded. This was repeated three times and the mean calculated.

3.1.2 Seed purity analysis

A sub-sample of the 1000g maize seed of each sample was sorted by hand into pure seed, broken seed, shriveled seed, discoloured seed and pest-damaged seeds by visual examination and their percentages by weight was determined. The components were weighed using an electronic weighing balance.

3.1.3 Fungi associated with the seeds

One hundred (100) maize seeds were selected at random from each certified and farmer-saved seed samples and disinfected separately with 10% commercial bleach and (1% chlorine) to get rid of all superficial-borne organisms. Ten (10) seeds were then plated on 9-cm Petri dish half-filled with PDA medium. This was done in the lamina flow chamber to prevent contamination. Petri dishes were then set on a clean working table sterilized with ethanol in the transfer chamber in the Plant Pathology Lab, Department of Crop and Soil Sciences. After seven days, fungal growth on maize samples was examined and identified under a compound microscope (Hund Walls, Germany). The fungi identification was done with the help of identification manuals (Hunter and Barnett, 1978).

3.1.4 Identification of location of fungi in maize seed

Randomly, 20 maize seeds were selected from pure seeds of certified and farmer-saved seeds from each sample and soaked separately in sterile water beakers for 24h. The seeds were removed and then separated in to embryos, endosperms, and cotyledons using a sharp knife. A set of five samples from embryos, endosperms and cotyledons from each seed sample and plated on Petri dishes half–filled with PDA. They were three replications. After seven days, the fungi growth on each part of maize samples were examined and identified as described above.

3.1.5 Germination test of maize seeds

Four hundred (400) maize seeds from each maize seed sample were selected at random and counted from the well-mixed pure seed under certified and farmer-saved seed samples. Seed trays filled with the same type of moistened sterilized river sand were used to sow the maize seeds. Sown seeds were then left at the plant house for seven days after which seedlings were counted. The seedlings were then sorted out into normal, abnormal seedlings, dead seeds and ungerminated seeds.

3.1.6 Seedling growth rate test

From each sample of pure maize seeds, 25 seeds were selected randomly and placed on filter paper moistened with 4ml distilled water inside sterilized Petri dish. Complete randomized design with four replications was used. After 5-10 days, counting and removal of all the germinated seeds were done every 12h. Seeds were considered germinated when the radical protruded by 2-

4mm. Germination index was calculated using the equation $\sum (t*n)/\sum n$ (Salehzade *et al.*, 2009), where n is the number of germinated seeds and t the number of hours from the beginning of the germination test.

3.1.7 Data collected

3.1.7.1 Seed purity analysis

Seed moisture content, weight of pure, broken, shriveled, discoloured, and pest-damaged seeds.

3.1.7.2 Fungal evaluations

The number of the infected seeds and location on seeds by fungi and type of associated fungi.

3.1.8 Germination test

The number of normal, abnormal seedlings, ungerminated, and dead seeds.

3.2 Field evaluation of the maize seed samples

Field evaluation for all seed types from each location was done at the Department of Crop and Soil Sciences Plantation Section, KNUST, Kumasi. The land was slashed, ploughed and harrowed. The experiment was 2x5 factorial in randomized complete design with four replications. The experimental plot was planted at the spacing of 80cm x 40cm with three seeds per hill, one thinned, two weeks after sowing. NPK fertilizer (15: 15: 15) was applied at two weeks after emergence and top-dressed with urea at six weeks after emergence. Weeds were controlled by manual weeding using hoe and cutlass.

3.2.1 Data collected

3.2.1.1 Soil sampling and analysis

Before planting the trial, representative soil sample was taken at different parts of the field. The soil auger was used to sample soil at randomly selected sites on each plot. The samples were taken at a depth of 0-15cm. They were then mixed thoroughly by hand and air-dried on laboratory bench. The soils were sieved through a 2mm, and 0.5mm sieves. Working samples were acquired from each submitted sample and analyzed for selected soil physical and chemical properties such as soil pH, organic carbon, total N, available phosphorus, available potassium, cation exchange capacity (CEC). The analysis was done at the laboratory of the Department of Crop and Soil Sciences, KNUST, Kumasi.

3.2.1.2 Phenological and growth parameters

Seedling emergence: Seedling emergence at two weeks after sowing was recorded by counting all emerged seedlings from each plot. Means were then calculated for each treatment.
Growth analysis: By using measuring tape, six plant height measurements were taken randomly from each plot at 20, 40, 60, 80 and 100 days after planting.

Days to tasselling: Days to tassel was taken by counting at the time 50% of the plants in a plot had tasselled. Days to silking: Days to silking was taken by counting at the time 50% of the plants in a plot had silk emerged. Plant girth: Plant girth measurement was taken using caliper. Six plants randomly selected from each plot at 60 days after planting were taken by measuring the plant thickness. Days to physiological maturity (DPM): Days for plants to reach physiological maturity per plot was recorded at the time of creation of a black layer at the point of attachment of the kernel through the cob. Disease incidence: Disease symptoms observed on plants were evaluated by scaling systems (1-5)

3.2.2 Data on yield components

Kernels per cob: Number of kernels per six cobs randomly selected per plot were counted after the crops were harvested and sun-dried.

Thousand seed weight (g): It was determined from 1000 grains weighed randomly selected from each plot and weighed using electronic sensitive balance (Sartorius Company, Germany).

Grain yield (kg/ha): After harvesting the cobs of each plot and sun drying, seeds were shelled by hand. Then the seed dried to adjust moisture contents of 12.5% and weighed the grains using electronic balance.

3.3 Data Analysis

Data were analyzed using Gen stat statistical software package (version 12). Means of laboratory and field data were separated using Tukey test at 5% level. Correlation coefficients were done between seed quality parameters data of the lab work and growth/yield parameters of the field evaluation. The results were presented as graphs, pictures, charts and tables.

CHAPTER FOUR

4.0 RESULTS

4.1. Purity analysis of certified and farmer-saved maize seeds

4.1.1 Seed moisture content of the maize seeds

The mean moisture content of seed samples from farmer-saved seed was significantly different ($p<0.05$) from certified seed samples across the ecological zones. However, there was no significant variation ($p>0.05$) within farmer-saved seeds and certified seeds throughout the zones.

The highest moisture content was registered in farmer-saved seeds of Semi-deciduous (14.6%), followed by the Transitional zone (14.4%), then the Rainforest zone (14.3%) and the lowest was recorded in Coastal Savannah and Guinea Savannah zones (14.1%) (Figure 4.1)

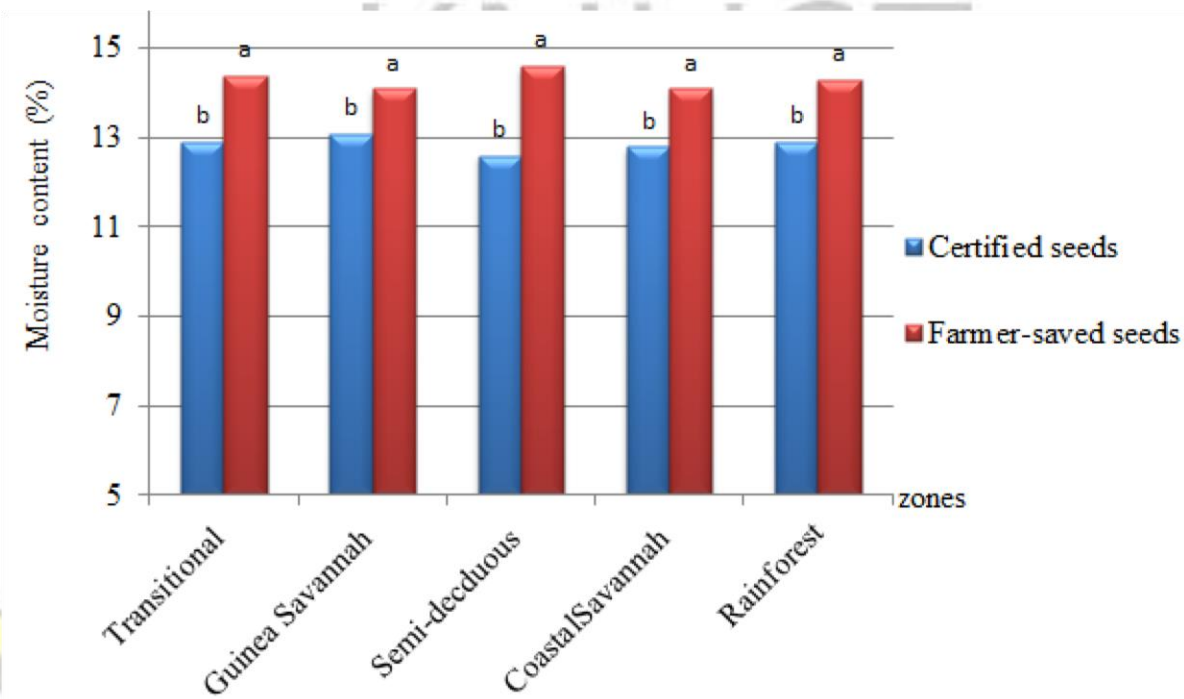

Figure 4.1. Maize seed moisture content from different zones

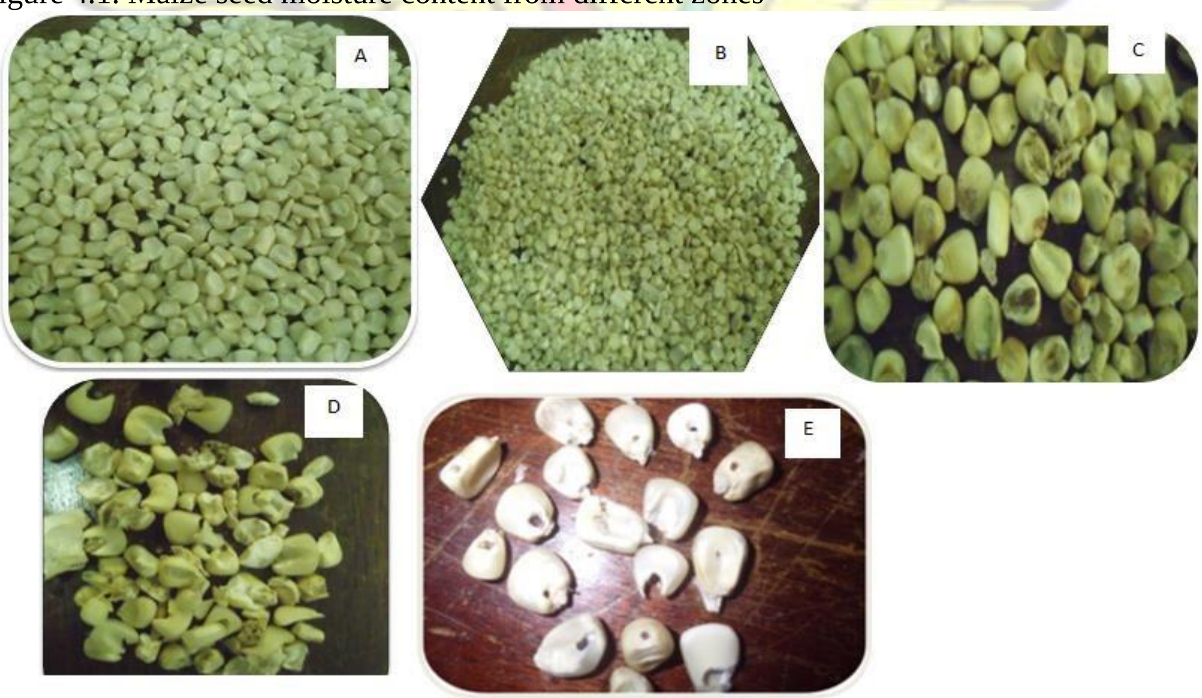

Figure 4.2. Seed types found purity analysis (A) Pure seeds (B) Shriveled seeds (C) Discoloured seeds (D) Broken seeds (E) Pest damaged seeds.

4.1.2 Pure seeds

The results of pure seeds (Figure 4.2A) per1000g of working sample seed measured in terms of percentage. Certified seed samples significantly ($p<0.05$) recorded the maximum values than farmer-saved seed samples across the study zones. The highest value was observed in Coastal Savannah Zone and the lowest was from Rainforest Zone. Despite that, there was no significant difference ($p>0.05$) within certified seeds across ecological zones and the same within farmersaved seeds but the seeds from Rainforest Zone was significantly different ($p<0.05$) from the rest of the zones. Under certified seed systems, the percentage purity are as follows: the Coastal Savannah Zone (95.10%), Semi-deciduous (94.57%), Transitional (94.53%), Guinea Savannah (94.13%), and Rainforest Zone (93.73%), respectively. In farmer-saved seeds coastal Savannah (80.53%), Transitional (79.93%), Guinea Savannah (79.80%), Semi-deciduous (77.43%) and Coastal savannah Zone (74.4%) see (Figure 4.3).

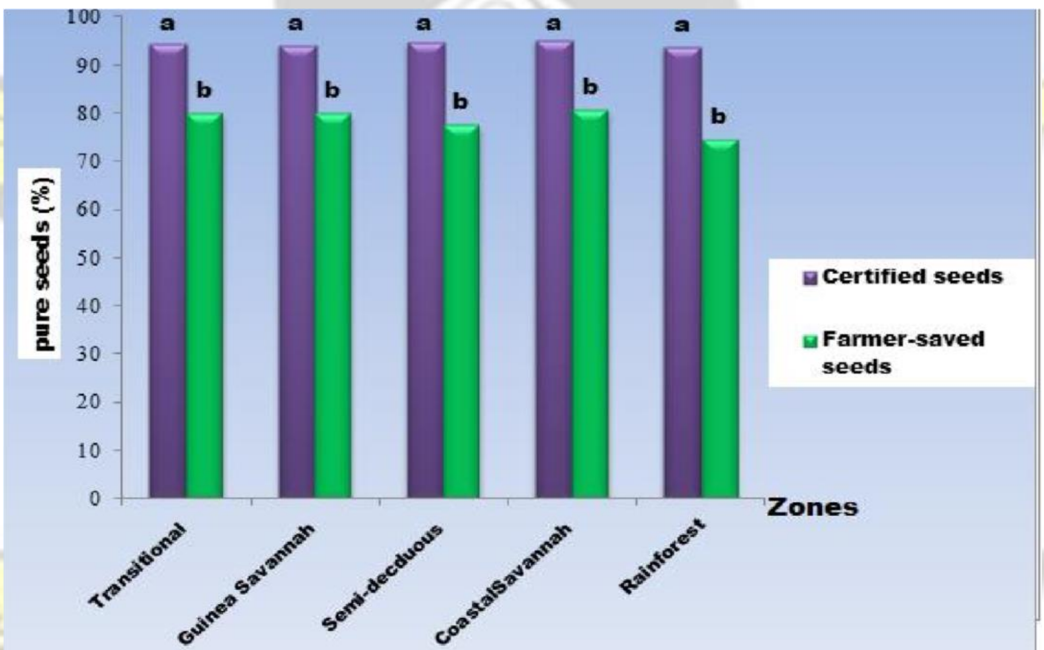

Figure 4.3.Mean maize seed purity under certified and farmer-saved seeds in Ghana.

4.1.3 Broken seeds

The maximum broken seed (Figure 4.2D) value was recorded under the farmer-saved seeds across ecological zones. Although, certified seed system had significantly ($p<0.05$) lower broken seeds than farmer-saved seeds across all zones, there was no significant ($p>0.05$) variation within certified seed system across the zones. However, under farmer-saved seed, seeds from Transitional zone were significantly different ($p<0.05$) from Rainforest zone but similar to Coastal Savannah, Semi-deciduous, and Guinea Savanna zones (Figure 4.4).

4.1.4 Discoloured seeds

The highest mean value of discoloured seed (Figure 4.2C) was observed from farmer-saved seeds across all the study zones and also there was significant ($p<0.05$) variation between certified and farmer-saved seeds across ecological zones. However, discoloured farmer-saved seeds in the Rainforest zone was significantly different ($p<0.05$) from other zones and that of all certified seeds from the five agro ecological zones (Figure 4.5).

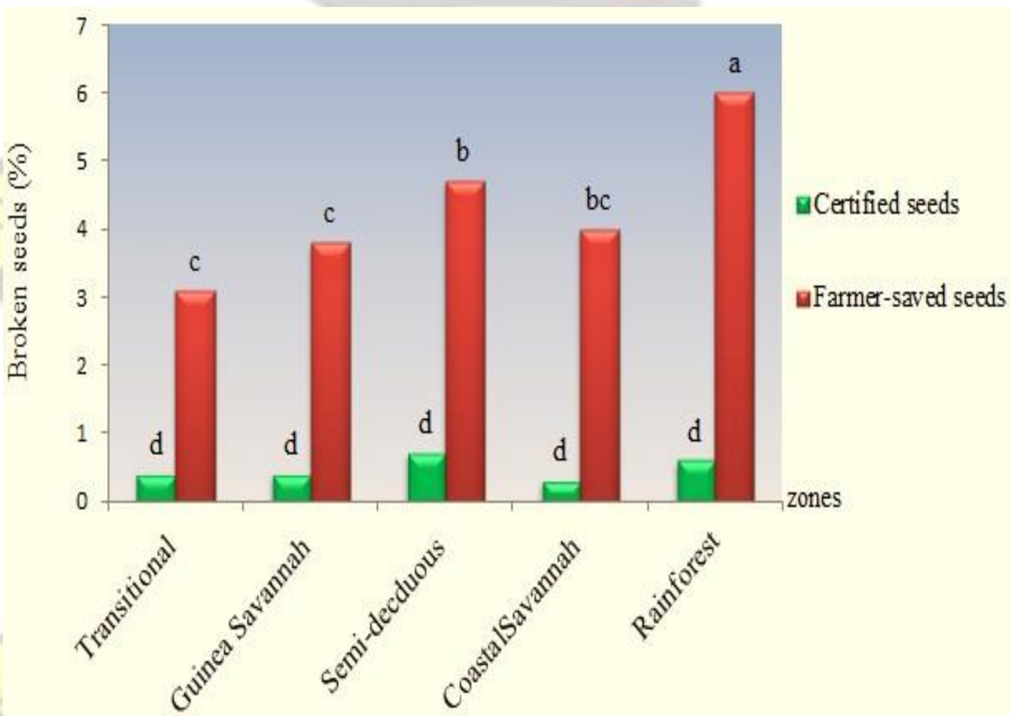

Figure 4.4 .Broken maize seeds of certified and farmer-saved seeds from different zones of Ghana

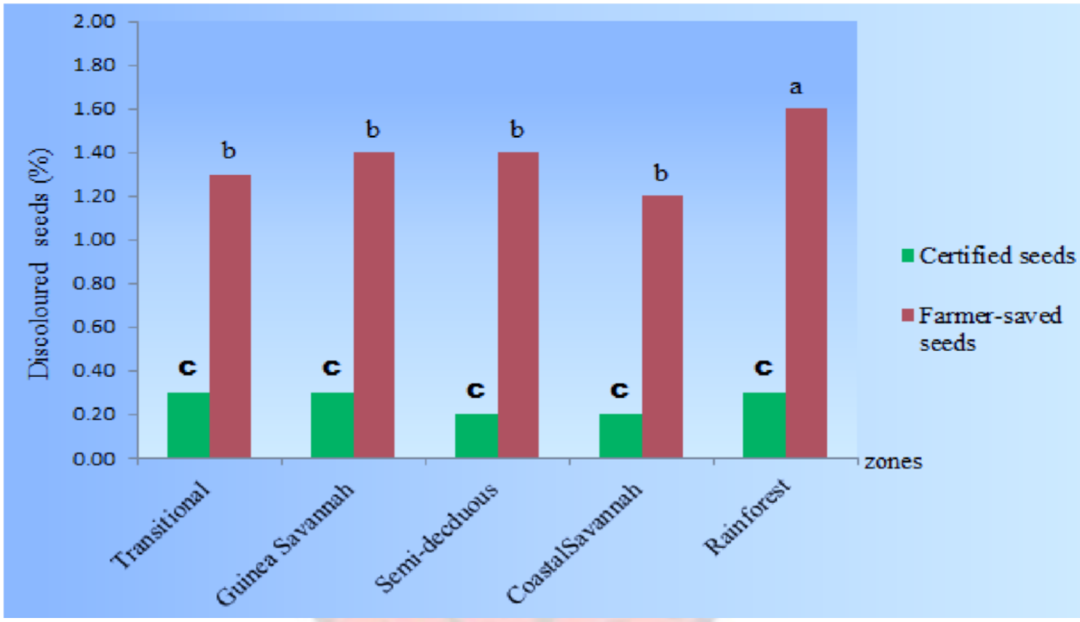

Figure 4.5. Discoloured maize seeds from certified and farmer-saved seeds from different zones of Ghana

4.1.5 Pest-damaged seeds

There was no significant difference ($p>0.05$) observed in pest-damaged seeds (Figure .4.2E) under the certified seed samples taken from the various zones. There was significant difference ($p<0.05$) across zones within the farmer-saved seeds. Rainforest zone recorded the highest value (6.0%) in pest-damaged seeds (Figure 4.6).

4.1.6 Shrivelled seeds

The mean shriveled seed from certified system in Rainforest zone was significantly different ($p<0.05$) from Transitional, Guinea Savannah and Semi-deciduous zones but similar to Coastal Savannah, and Transitional zones for farmer-saved seeds (Figure 4.2B). There was significant difference ($p<0.05$) between certified and farmer-saved seeds across ecological zones (Figure .4.7).

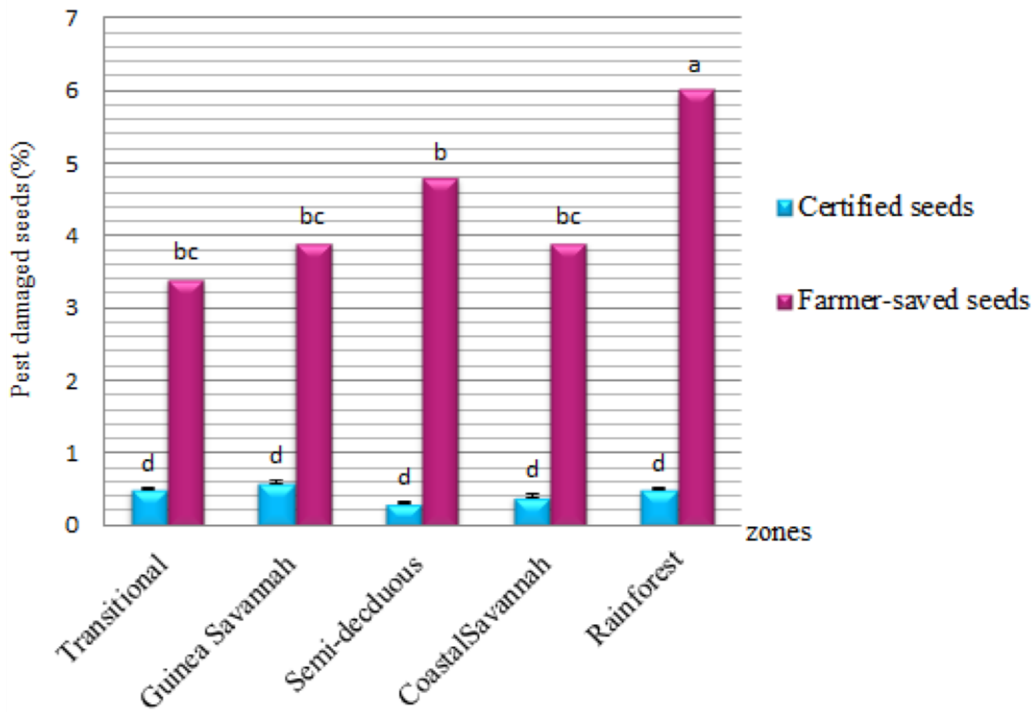

Figure 4.6. Pest damaged maize seeds under certified and farmer-saved seeds from different zones of Ghana

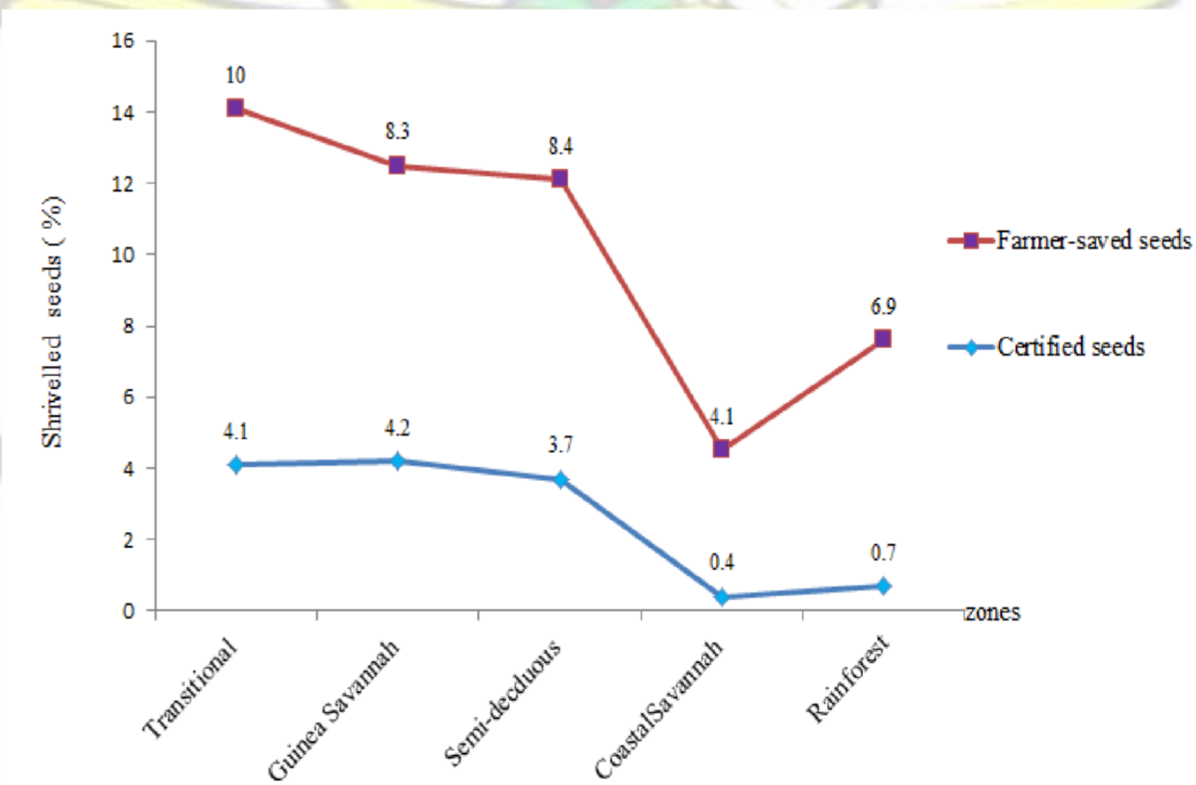

Figure 4.7. Shriveled maize seeds of certified and farmer-saved seeds from different zones of Ghana.

4.2 Germination tests

4.2.1 Normal seedlings

The mean germination per four hundred (400) seeds measured in terms of percentage from the five agro-ecological zones of Ghana showed that the highest normal seedling (Figure 4.8A) percentage was recorded under the certified seed grower system across the zones. The percent germination was recorded as follows; the Rainforest zone (85.2%), Guinea Savannah zone (84.9%), Transitional zone (84.2%), Coastal Savannah zone (83%) and Semi-deciduous zone (79.8%) in descending order (Table 4.1). For the farmer-saved seeds, the Coastal Savannah produced the highest mean normal seedling followed by Guinea Savannah zone; Transitional zone, Semi-deciduous zone, and Rainforest zone (Table 4.1). There was no significant variation (p>.0.05) between certified seed growers across the zones. However, there was significant variation ($p<0.05$) between certified and farmer-saved seeds across ecological zones (Table 4.1).

4.2.2 Abnormal seedlings

The germination tests showed that, the farmer-saved seeds produced more abnormal seedlings (Figure 4.8B) than the certified seeds in all samples tested from the five agro-ecological zones. There was no significant different ($p>0.05$) between the certified seeds across the agro-ecological zones. However, there was significant variation ($p<0.05$) between certified and farmer- saved seeds across various zones. The highest values of abnormal seedlings were recorded in Semideciduous zone (20.2%), followed by Transitional (19.5%), Rainforest (19.4%), Guinea Savannah (18.9%) and Coastal Savannah zones (17.9%). Under certified seed system, percent abnormal seedlings recorded were as follows; Semi-deciduous (13.4%), Coastal Savannah

(10.8%), Guinea Savannah (10.3%), Transitional (9.7 %) and Rainforest zones (9.6%) (Table 4:1).

4.2.3 Dead seeds

The farmer-saved seeds produced more dead seeds (Figure 4.8c) than the certified seeds across the study zones. The value recorded in Guinea Savannah zone was less than Rainforest zone but similar to Semi-deciduous zone and there was no significant variation ($p<0.05$) between zones within farmer-saved seed system. However, there were significantdifferences ($p<0.05$) within certified seeds across ecological zones while there was no significance difference ($p>0.05$) among certified seeds across various agro-ecological zones (Table 4:1).

4.2.4 Ungerminated seeds

The highest percentage of ungerminated seeds was recorded under farmer-saved seed system than in certified seed system (Table 4.1). There was no significant difference ($p>0.05$) in certified seed systems across various zones. However, there was significant difference ($p<0.05$) between certified and farmer-saved seeds across zones (Table 4.1).

Figure 4.8. Maize seed germination tests (A) Normal seedlings (B) Abnormal seedlings (C) Dead seeds.

4.2.5 One hundred (100) seed grain weight

The mean 100 seed gram weight under certified and farmers-seed systems indicated that, there was significant difference ($p<0.05$) between the two seed grower systems across the ecological zones. However, the farmer-saved seed from the Transitional zone was the heaviest followed by certified seeds from the same zone and the lowest value was recorded in Semi-deciduous farmersaved seeds. However, there was significant difference ($p<0.05$) between the two systems within and across the zones (Table 4.1).

Table4.1 Germination test of certified and farmer-saved maize seeds from five Agro-ecological zones of Ghana

		Seed germination tests (%)					
Ecological zones	Seed types	Normal seedlings	Abnormal seedlings	Dead seeds	Ungerminated seeds	Hundred seed	Germination index
Transitional	CS	84.2a	9.7b	3.3c	2.6b	31.5ab	103.0a
	FS	63.8b	19.5a	9.3a	7.0a	34.4a	99.4a
Guinea Savannah	CS	84.9a	10.3b	3.0c	2.4b	34.4a	92.9a
	FS	64.3b	18.9a	9.7a	7.2a	27.1bc	103.7a
Semi-deciduous	CS	79.8a	13.4b	4.7bc	2.3b	28.6bc	97.2a
	FS	61.6b	20.2a	9.7a	8.3a	29.8ab	100.4a
Coastal Savannah	CS	83.0a	10.8b	4.1c	2.2b	23.7c	97.6a
	FS	65.3b	17.9a	8.7ab	8.1a	27.0bc	95.8a
Rain forest	CS	85.2a	9.6b	2.9c	2.5b	29.9ab	103.1a
	FS	61.5b	19.4a	10.3a	8.8a	28.2bc	93.0a
CV (%)		5.2	16.6	19.9	17.1	11.9	7.2

CS= certified seeds, FS= farmer-saved seeds. Letters followed by the same letters are not significant ($p>0.05$) according to Tukey test.

4.3 Fungi associated with maize seeds

4.3.1 Aspergillius flavus

The incidence of *A. flavus* was recorded in all zones, and in both seed systems. *Aspergillius flavus* infection was generally higher in the farmer-saved seed system. The total value for the various zones, showed that, Guinea Savannah zone had the highest value (67%), followed by Coastal Savannah zone (60%), Semi-deciduous zone (57%), Transitional zone (53%) and Rainforest zone (30%) (Table 4.2). under the certified seed system, Semi-deciduous zone recorded 43%, followed by Coastal Savannah zone (37%), Transitional zone (33%), Guinea Savannah zone (30%), and Rainforest zones (30%) (Figure 4.9).

4.3.2 Aspergillus niger

From the results (Figure 4.10) *Aspergillus niger* recorded the highest infection under certified seeds. Rainforest zone recorded (43%), Coastal Savannah (33%), Semi-deciduous (20%), Guinea Savannah (17%) and Transitional zones (10%) in decreasing order. On the other hand, the results in (Table 4.2) indicated that, the farmer-saved seeds infections wereas follows, Rainforest zone (30%), followed by Transitional (20%), Guinea Savannah zone (10%), Coastal Savannah zone (7%), and Semi-deciduous zone (3%).

4.3.3 C*olletotrichum* species

Colletotrichum species was also recorded in all zones and in both seed grower systems, but the highest infection was registered in the farmer-saved seed grower system. Rainforest zone had the highest infection in farmer-saved seeds (23%), followed by Guinea Savanna zone (17%). The Semi- deciduous, Coastal Savannah and Transitional zones recorded the same infection of (13%) as indicated in Figure 4.11. Although, under certified seed system, Transitional, Guinea Savannah and Coastal Savannah zones had the same value of 13%, and Semi-deciduous zone (10%) but no infection was recorded in the Rainforest zone (Figure 4.11).

4.3.4 *Penicillium* species

Figure 4.12 show the fungus recorded in both the farmer-saved and certified seed systems from all sampled zones, but the highest infection was observed in farmer-saved seed system. Infections in the Semi- deciduous zone was (33%), followed by Coastal Savannah and Transitional zones (10% each). Rainforest zone (7%) and Guinea Savannah zone (3%). Under certified seed system, the highest infection was in the Guinea Savannah zone (13%), followed by Transitional and Semi-deciduous zones (10% each), and Coastal Savannah and Rainforest zones also having the same value 3%.

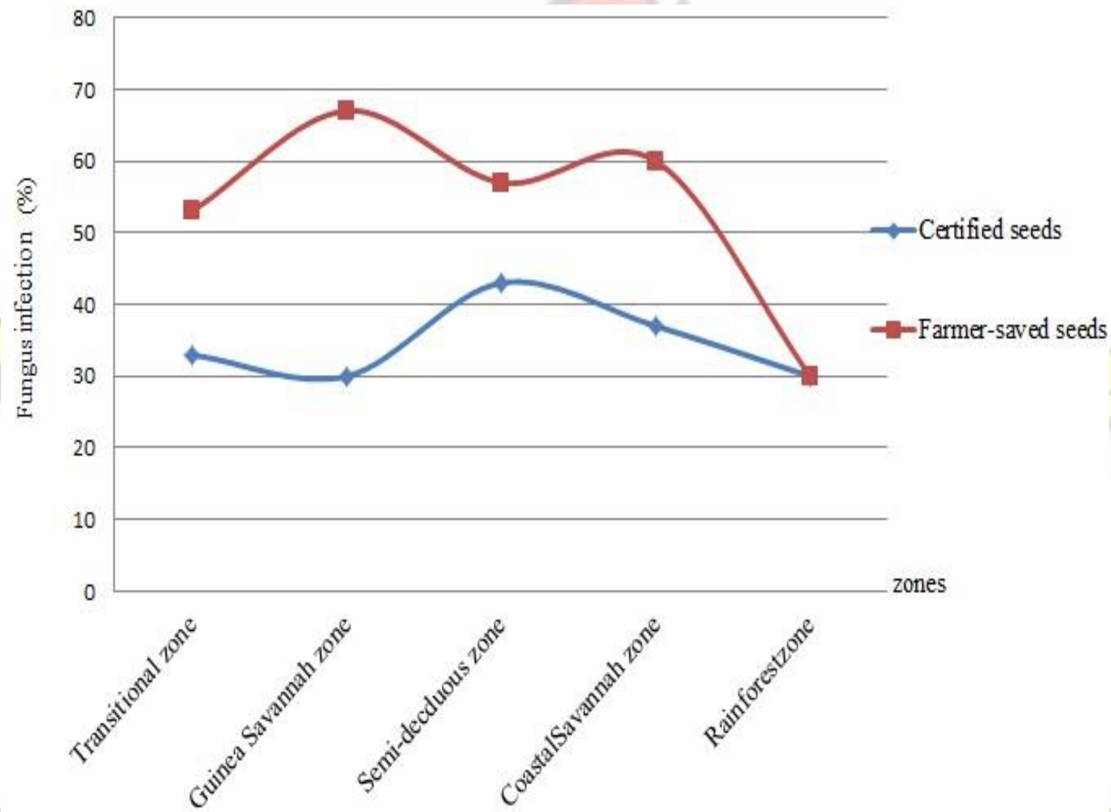

Figure4.9. *Aspergillius flavus* infection in maize seeds from different zone of Ghana

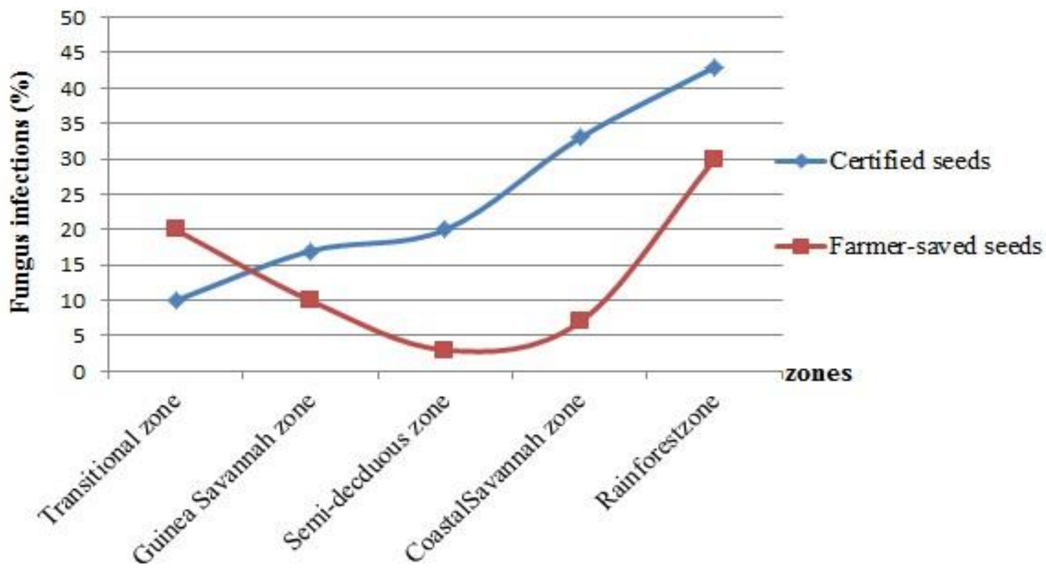

Figure4.10 . *Aspergillius niger* infections in maize seeds of certified and farmer-saved seed systems

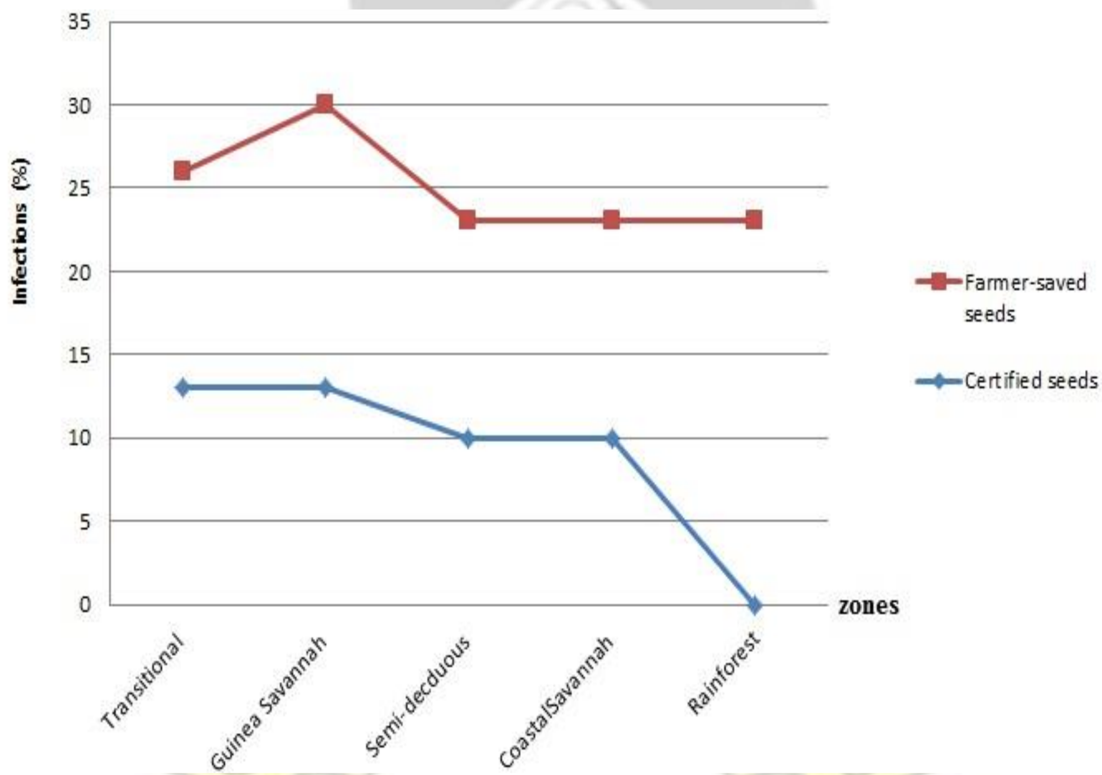

Figure 4.11. *Colletotrichum* species infections in maize seeds from Ghana

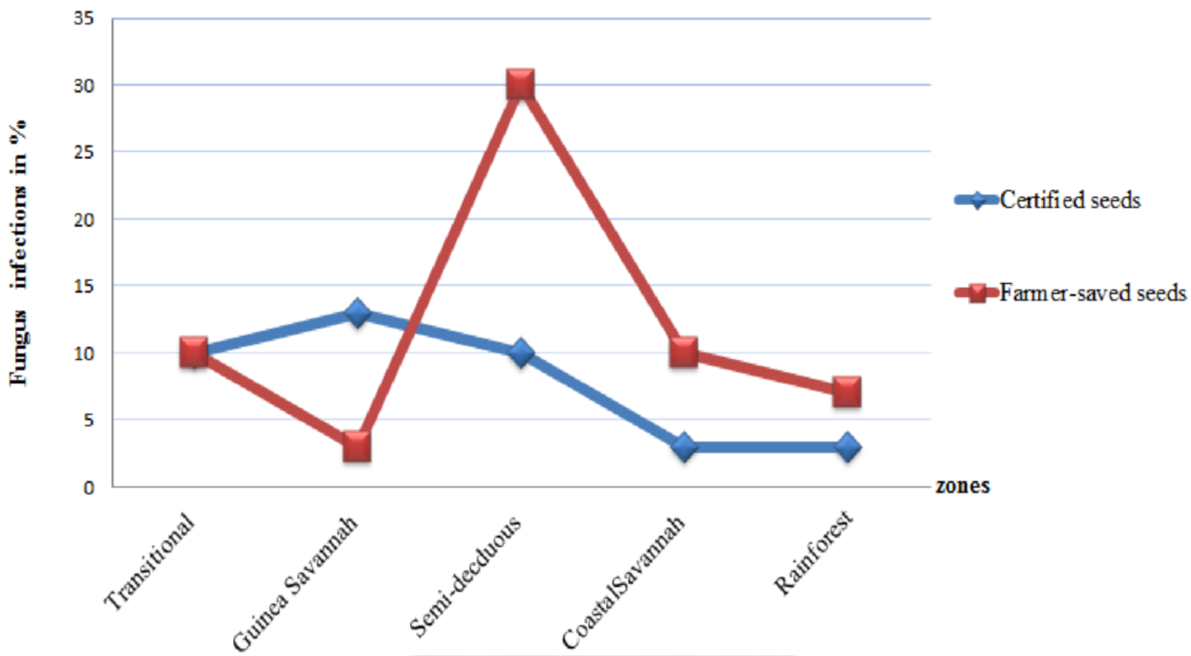

Figure 4.12. *Pencillium* species infections in maize seeds under certified and farmer-saved seeds from Ghana

4.4 Identification of location of fungi in maize seeds

4.4.1 Aspergillus flavus

The identification of fungi location in maize seed showed that, fungi were found in embryo, cotyledon and endosperm under certified and farmer-saved seed systems across all zones. Fungus was not found in the endosperm of the farmer-saved seeds in the Semi-deciduous zone, and embryo and endosperm in the Rainforest zone. However, the incidences of fungi were observed in the endosperm of certified seeds. Guinea Savannah zone recorded 60%, followed by Transitional zone (47%), Coastal Savannah zone (37%), and Semi-deciduous zones (27%) of fungal infection (Table 4.2).

4.4.2 Aspergillus niger

Aspergillus niger was recorded in all zones under both seed grower systems. However, the highest infection was observed also in endosperm under farmers' seed grower system. Semideciduous zone had the highest percentage (100%) infection, followed by Rainforest zone (61%), Coastal Savannah zone (53%), and Transitional zone (33%). It was also observed under certified seed system in Rainforest zone (87 %) and (47 %) in Guinea savannah zone (Table 4.2).

4.4.3 *Colletotrichum* species

This fungus was not found on cotyledon under both seed systems in the study zones (Table 4.2) whereas it was found on endosperm and embryo of the seeds from all zones. The Transitional zone (CS), Guinea Savannah (FS), Coastal Savannah (CS), and Rainforest (FS) recorded same infection incidences (47%). but the other zones had Transitional (FS) 35%, Guinea Savannah (CS) 20%, Semi-deciduous (CS) 12%, Coastal Savannah (FS) 48 %, and Rainforest (FS) 28%.

On the other hand, on endosperm, the Transitional zone (FS) recorded the highest infection (40%), followed by Guinea Savannah (FS) 33%.

4.4.4 *Penicillium* species

Penicillium was found on all the tested components of the seeds in different amount of infections. However, it was not found on cotyledon except in the Transitional zone under the farmer-saved seeds. On the endosperm, the Guinea Savannah (CS) and Rainforest (FS) had similar percent

(20%) and also in the semi-deciduous (CS) and Rainforest (CS) recorded similar (13%) Table 4.2.

4.4.5 *Curvlaria* species

Curvlaria was found only in the embryo under certified and farmer-saved seed systems across the zones. The Transitional zone (CS) recorded 7%, followed by Semi-deciduous zone (FS) 8%, Coastal Savannah zone (FS) 23%, and Rainforest zone (FS) 20%. From the results of the infections in the embryo, endosperm and cotyledon under both systems, infection was the highest in the endosperms (Table 4.2).

Table 4.2. Locations of fungi in seed maize component parts from certified and farmer-saved seed systems of Ghana

Ecological zones	Seed types	Fungi seed component parts infection (%)														
		A f			A n			Coll			Penc			Curv		
		Cot.	Emb.	Endo	Cot.	Emb.	Endo	cot.	Emb.	Endo	Cot.	Emb.	Endo	Cot.	Emb.	Endo
Transitional	CS	33b	13c	47b	20c	27cd	20e	0	47a	27bc	0	7c	7d	0	7b	0
	FS	7e	22b	20e	67a	43bc	33d	0	35b	40a	0	0	7d	0	0	0
Guinea Savannah	CS	7e	15c	60a	7d	45bc	20e	0	20bc	7d	0	20a	13c	0	0	0
	FS	47a	0	20e	13cd	53b	20e	0	47a	33b	0	0	27b	0	0	0
Semi-deciduous	CS	13d	6d	27d	53b	62a	47c	0	12c	13c	0	13b	13c	0	0	0
	FS	20bc	37a	0	7d	20d	100a	0	35b	0	47a	0	0	0	8b	0
Coastal Savannah	CS	28b	25b	37c	17cd	28cd	7f	0	47a	7d	0	0	50a	0	0	0
	FS	13d	22b	27d	42b	7e	53c	0	48a	20bc	0	0	0	0	23a	0
Rain forest	CS	27b	23b	0	47b	35c	87b	0	28bc	13c	0	13b	0	0	0	0
	FS	7e	0	20e	20c	13d	61bc	0	47a	19bc	0	20a	0	0	20a	0
LSD (0.05)		12.8	11.5	18.3	21.2	15.3	24.2	0	19.6	17.6	23.1	20.5	13.1	0	16.7	0

Af= Aspergillus fluvas, An= Aspergillus niger, Coll =Colletotrichum sp, ,Penc. Pencillinum sp, Curv= Curverlaria. sp, CS=Certified seeds, FS= Farmers saved seeds, cot=cotyledon, Emb=embryo, Endo=endospem. Letters followed by the same letters are not significantly different (p>0.05) according to Tukey test.

4.5 Field evaluation of the maize seed samples

4.5.1. Soil chemical and physical properties of the experimental site

Selected soil chemical and physical properties were analyzed for composite soil (0-15 cm) from the samples collected from each replication before planting. The results indicated that, the soil (PH) was 6.5, which was nearly neutral. According to FAO (2008), suitable pH range for most crops is between 6.5 and 7.5 in which crop nutrient availability is optimal. This shows appropriateness of the soil response in the trial site for ideal crop growing and yielding. Table 4.3. Selected physicochemical properties of the experimental soil before planting

Sample name		OC	OM	Total	Av.P	EC (Cmol/kg G1)			
	PH		(%)	(%)	N (%)	(ppm)	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
Soil	6.52		0.56	0.96	0.113	6.71	4.01	1.87	0.09	0.07

4.5.2 Plant growth analysis of maize after planting

The plant growth analysis result at 20 days after planting (DAP) displayed that, there was significant difference ($p<0.05$) between certified and farmer-saved seed systems between the zones. However, there was no significant variation ($p>0.05$) within certified seeds between the agro-ecological zones. There was also no difference ($p>0.05$) under farmer-saved seeds between ecological zones (Table 4.4). At 40 days after planting,the growth rate analysis was significantly dissimilar ($p<0.05$) between certified and farmer-saved seeds. There was no significant variation ($p>0.05$) recorded within the certified seeds across the zones (Table 4.4).

The plant growth analysis 60 DAP showed that, there was substantial difference ($p \leq 0.05$) between certified and farmer-saved seeds. Farmer-saved seeds from Transitional, Semi-deciduous and Rainforest recorded better growth compared with certified seeds from the same zone. However, the certified seeds from Transitional, Guinea Savannah, and Coastal savanna zones were similar from that of farmer-saved seeds from Transitional zone (Table 4.4).

The growth at 80DAP reduced to compare to 20DAP, 40DAP, and 60DAP (Table 4.4). Under the certified seed system, there was no significant difference ($p>0.05$) between the Transitional, Semi-deciduous and Rainforest zones, but significantly different ($p<0.05$) from Guinea Savannah and Coastal Savannah zones. On the other hand, under farmer-saved seed system, there was no significant difference ($p>0.05$) between the Transitional, Semi-deciduous, Coastal Savannah, and Rainforest zones, but significantly different ($p<0.05$) from the Guinea Savannah zone (Table 4.4).

The plant growth was very low compared with the earlier growth analysis rates. Under certified seed system, there was no significant difference ($p<0.05$) across the zones except the Transitional zone. However, under farmer-saved seed system, the Guinea Savannah and Semi-deciduous zones were significantly different ($p<0.05$) from Transitional, Coastal Savannah and Rainforest zones (Table 4.4).

4.5.3 Plant girth measurement

Mean plant girth measurement under certified seed system, indecated that the Rainforest zone was significantly different ($p<0.05$) from the Transitional, Guinea Savannah, Semi-deciduous, and Coastal Savannah zones. In the farmer-saved seed system, the Transitional and Semideciduous zones showed similar, in addition Coastal Savannah and Rainforest zones also recorded similar value, but significantly different ($p<0.05$) from the Guinea Savannah zone. However, there was no significant variations ($p>0.05$) between certified and farmer-saved seeds across the zones (Table 4.4).

Table 4.4 Mean of plat growth analysis at deferent day after planting from certified and farmers saved seed system from five agro-ecological zones of Ghana planted in 2015 minor season.

		Mean Maize plant Growth Analysis at different day after planting					
Ecological zones	Types	20 DAP	40 DAP	60 DAP	80 DAP	100 DAP	PG
Transitional	CS	34.8 a	81.1 a	52.2ab	9.3 b	1.3abc	15.8ab
	FS	25.0 b	68.6b	62.8 a	15.5ab	3.3ab	15.6ab
Guinea Savannah	CS	35.6a	81.6a	51.9ab	17.1ab	0.2abc	15.7ab
	FS	27.1 b	66.9 b	51.8ab	21.3 a	1.1abc	16.2 a
Semi-Deciduous	CS	36.1 a	80.7 a	51.7ab	9.4 b	0.7abc	15.9ab
	FS	26.7 b	68.8 b	64.7 a	12.7ab	1.6abc	15.9ab
Coastal Savannah	CS	33.3 a	81.3 a	58.7ab	13.0ab	-0.8 c	15.3ab
	FS	27.1 b	68.8 b	54.ab	15.4ab	3.4a	14.5 b
Rainforest	CS	34.3 a	81.3 a	60.6 a	9.6 b	-0.2bc	16.4 a
	FS	27.7b	73.7 b	46.1 b	18.1ab	3.3ab	14.9ab
mean		30.2	75.28	55.4	14.1	1.38	15.62
L.S.D. (5%)		3.24	6.42	11.92	9.06	3.039	1.5
CV%		13	10.5	26.6	79.2	271.5	11.9

DAP= day after planting, PL =Plant, GR = girth, mm = mill meter, CS=certified seed, FS= Farmers saved seeds, PG=plant girth, L.S.D=Least significant
differences of means (5% level), CV= coefficients of variation. Figures in a column followed by different letters differ significantly but with common letter (s)
do not differ significantly at the 5% level of probability.

4.6 Impact of seed quality on phenological and growth parameters

4.6.1 Seed emergence

The mean seed emergence after two weeks of planting, from the five agro-ecological zones of Ghana planted in 2015 minor season indicated that the seeds from certified seed growers had uniform seedling emergence than farmers-saved seeds across all ecological zones, and also, there was significant difference ($p<0.05$) between the certified and farmer-saved seeds (Table 4.5).

4.6.2 Days to 50 % tassel

The study revealed that the farmer-saved seed systems from all ecological zones took longer days to tassel. There was substantial variance ($p<0.05$) between farmers-saved and certified seeds across the various ecological zones but there was no significant difference ($p>0.05$) within farmers-saved seeds across zones. Nevertheless, mean days to tassel of the certified seed from Semi-deciduous and Coastal Savannah zones were significantly different ($p<0.05$) from Transitional but similar to that of Rainforest and Guinea Savannah zones (Table 4.5).

4.6.3 Days to 50% silking

When compared certified and farmer-saved seed systems from the five agro-ecological zones, the certified seeds took shorter days to silk than farmer-saved seeds across the ecological zones. Although, there was significant difference ($p < 0.05$) between certified and farmers-saved seeds across the study zones, there was no significant difference ($p>0.05$) between the certified seeds across zones, and also the farmers-saved seeds (Table 4.5).

4.6.4 Days to physiological maturity

The farmer-saved seeds matured earlier than the certified seeds across the zones. There was significant difference ($p<0.05$) between certified and farmer-saved seeds across the ecological zones except the Coastal Savannah zone, were variation was observed between certified seeds across zones and the farmer-saved seeds (Table 4.5).

Table 4.5 mean analysis of variance of maize agronomic parameters from certified and farmers saved system from five agro-ecological zones of Ghana planted in the 2015 minor season

Ecological zones	Seed types	SE (%)	DT	DS	PH	DPM	G/C	100GWT
Transitional	CS	92.0a	50.4c	61.4b	181.2	104.2b	248.8cd	34.3 a
	FS	78.1b	55.0a	65.2a	183.3	106.5a	230.0cd	34.08a
Guinea savannah	CS	93.1a	51.2bc	61.9b	189.5	103.9b	301.8abc	33.6a
	FS	74.7b	55.6a	65.8a	188.7	106.1a	255.7bcd	33.0a
Semi-Deciduous	CS	92.0a	52.1b	62.3b	189.1	104.1b	332.0.ab	32.8a
	FS	73.2b	55.6a	66.0a	188.8	106.1a	256.7bcd	27.5b
Costal savanna	CS	89.9a	51.8b	61.9b	187.5	102.6c	352.8a	27.3b
	FS	71.2b	55.2a	65.4a	184.6	106.2a	201.3d	26.8b
Rainforest	CS	92.0a	51.1bc	62.0b	184.8	104.1b	344.3a	26.7b
	FS	75.4b	55.0a	65.8a	181.3	106.2a	236.8cd	24.9b
CV (%)		12.7	2.6	3.0	8.1	1.2	9.8	12.8

SE=seed emergence, DT= day of 50 % tassel, DS =day of 50 % silk, PH= plant height in cent meter, DPM= Days to plant maturity, CS =certified seed, FS = Farmers saved seed, CV= coefficients of variation. Figures in a column followed by different letters differ significantly but with common letter (s) do not differ significantly differ significantly by Tukey test at 5 % level of probability.

4.7 Impact of seed quality parameters on plant population, grain weight and yield

4.7.1 Maize number of kernels per cob

The mean number of kernels per cob showed that under certified seed system, the Coastal Savannah zone (352), followed by the Rainforest (344), Semi-deciduous (332), Guinea Savannah (301), and Transitional zones. Under the farmer-saved seeds system, the Semi-deciduous zone (257), Guinea Savannah (256), Rainforest (237), Transitional (230), and Coastal Savannah (201) (Table 4.5).

4.7.2 One hundred (100) seeds grain weight

The hundred seed weight (g) indicated that, under certified seed system, the Transitional zone weighed 34.3, followed by Semi-deciduous (33.6), Guinea Savannah (32.8), Coastal Savannah (27.3), and Rainforest zones (26.7). On the other hand, under the farmer-saved seed system Transitional zone recorded 34.1, followed by Semi-deciduous (33), Guinea Savannah (28), Coastal Savannah (27), and the least of 25g Rainforest zones (Table 4.5).

4.8 Seed quality parameters impact on crop dry matter, disease and plant stand

4.8.1 Diseases found associated with maize plants

Maize streak disease was observed on some plants under both seed systems (Fig.4.13 A & B). The infection observed under farmer-saved seeds from Coastal Savannah (3.5) followed by Rainforest (2.4), Guinea Savannah (1.5), and Semi-deciduous zones (0.6). Under certified seed systems Coastal Savannah and rainforest zones had recorded similar (0.7), followed by Transitional zone (0.4) read Table 4.6.

4.8.2 Leaf dry weight

The leaf dry weights (g) showed that the certified seed systems from all agro-ecological zones were heavier than farmers-saved seeds. The results trend were as follows, Coastal Savannah (411g), Rainforest (373g), Coastal Savannah (346g), Transitional (345g), and Guinea Savannah

(325g). Under the farmer-saved seed system, the Guinea Savannah had the highest (204g), followed by the Transitional (199g), Semi-deciduous (196g), Coastal Savannah (184g), and rainforest zones (160g). The results indicated that there was significant difference (p<0.05) between certified and farmers-saved seeds across all agro-ecological zones, but there was no variation between farmer-saved seeds across ecological zones. However, certified seeds from Semi-deciduous zone was significantly different (p<0.05) from Guinea Savannah but similar to Rainforest, Coastal Savannah and Transitional zones (Table 4.6).

Figure 4.13 Streak virus infected maize plant (A) early growth stage (B) Selected leaf.

4.8.3 Cob dry weight

The cob dry weight (g) from the certified seeds from all ecological zones was significantly different (p< 0.05) from the farmers-saved seeds of the same zone. The results were as follows, under the certified seed system, the Guinea Savannah zone was 396g, Rainforest (394g), Semideciduous (385g), Coastal Savannah (374g), and Transitional zones (334g). In case of farmersaved seed system, the Transitional zone recorded the heaviest (258g), Guinea Savannah (208g), Semi-deciduous (195g), Coastal Savannah (187g), and least by Rainforest zones (184g). There was significant difference (p>0.05) between certified and farmer-saved seed systems across the ecological zones (Table 4.6).

Table 4.6 Mean analysis of disease, plant stands, and dry matter of maize planted at knust in 2015 minor season.

Ecological zones	Seed types	DA	PSA	LDWT	CDWT	TPDWT
Transitional	CS	0.4cd	3.6a	345.3ab	333.7a	918.6a
	FS	0.5cd	2.1b	198.9c	257.9b	663.9b
Guinea savanna	CS	0.2d	3.5a	325b	395.6a	955.2a
	FS	1.5bc	2.3b	203.8c	208bc	600.4b
Semi-Deciduous	CS	0.3cd	3.4a	410.8a	384.8a	1015.2a
	FS	0.6cd	2.2b	196.2c	195bc	579.3b
Costal savanna	CS	0.7cd	3.7a	346.0ab	374.2a	943.4a
	FS	3.5 a	2.1b	183.9c	186.8bc	579.7b
Rainforest	CS	0.7cd	3.8a	372.7ab	393.6 a	996.7a
	FS	2.4ab	2.3b	159.6c	184.3 c	557.7b
CV (%)		14.7	13.9	15.6	17.3	19.1

DA=disease aspect, PSA= plant stands, LDWT=Leaf dry weight, CDWT= cob dry weight, TPDW =Total plant dry weight, CS Certified seeds, FS=Farmers saved seeds, G/mean = Grand mean, L.S.D=Least significant differences of means (5% level), CV= coefficients of variation, figures followed by the same letters in column do not differ by Tukey test at 5 % probability.

4.8.4 Total plant dry weight

The mean total plant dry weight in the study indicated that there was significant difference ($p<0.05$) between certified and farmer-saved seeds in the entire zones. The results were as follows under certified seed system the Semi-deciduous had the heaviest (1015.2), followed by Rainforest (996.7), Guinea Savannah (995.2), and Coastal Savannah (943.4), and Transitional zones (918.6) in kg. From the farmer-saved seed system, the Transitional zone recorded the heaviest (663.9), followed by Guinea Savannah (600.4), Coastal Savannah (579.3), and then Rainforest zones (557.7) in kg (Table 4.6).

4.8.5 Evaluation of maize grain yield of certified and farmer-saved seeds

The mean grain yield of certified and farmer-saved seeds from the five agro-ecological zones of Ghana shows that, the certified seed systems gave higher yield than the farmer-saved seed systems across all zones. There was significant variation ($p<0.05$) between certified and farmersaved seeds across all the ecological zones. There was no significant difference ($p>0.05$) between certified seeds across the zones, and also, there was no significant difference ($p>0.05$) in yields between the farmer-saved seeds across the study zones. The yield recorded was as follows, under certified seed system Guinea Savannah was 664.1kg, followed by Coastal Savannah (597kg), Rainforest (586kg), Semi-deciduous (576kg), and Transitional zones (559.1kg) see (Fig.4.14). Under farmer-saved seed system, the highest yield was obtained in the Guinea Savannah zone 456.1kg, followed by Coastal Savannah (423kg), Rainforest (419.8kg), and then Transitional zones (390.5kg). The study revealed that, there was yield variation by 30% on average between certified and farmer-saved seed systems (Fig.4.14).

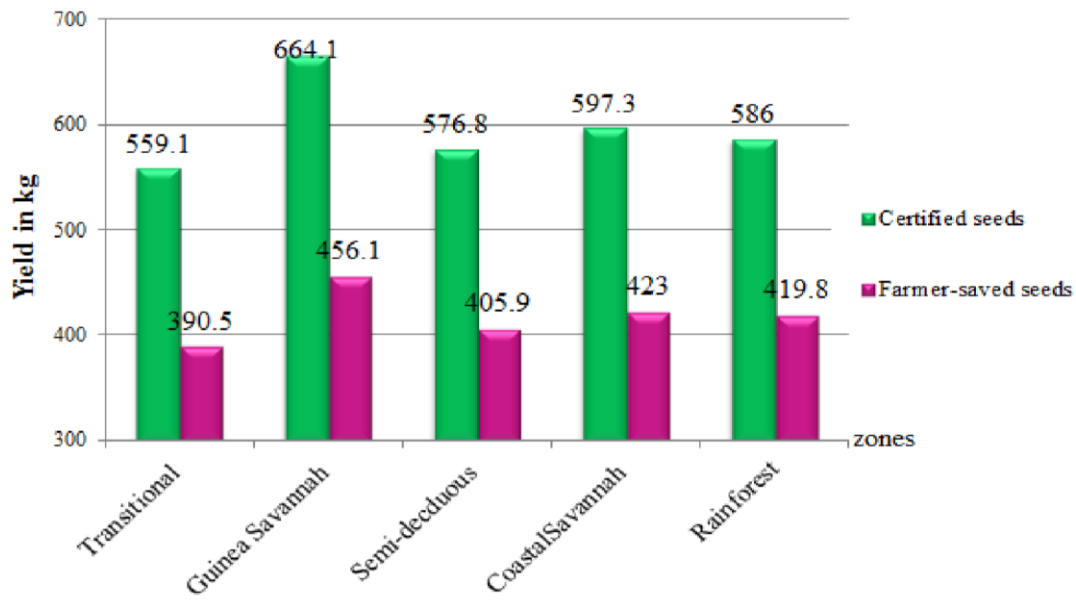

Figure 4.14. Mean yield of maize under certified and farmer-saved seeds from five agroecological zones of Ghana

4.9 Association of selected seed quality parameters, growth, maturity and yield trait

The correlation coefficient (r) showed positive significant association with yield per hectare (r =0.9), grain weight (r =0.9), plant stand (r =0.6) and seedling emergence (r =0.6). However, negative significant association was found with broken (r = -0.9), dead (r = -0.9), pest damaged (r = -0.9) and shriveled seeds (r = -0.9) but no significant relation with number of plants per metre square and grains per cob (r = -0.3 and r = -0.3) (Table 4.7). On the other hand, broken seed showed no significant association with the number of plants per metre square and plants stands (r = -0.3and 0.5, respectively). As observed from the correlation coefficient analysis, both dead and pest-damaged seeds were negatively correlated (r= -0.8) with number of plants per metre square and grain per cob but negatively correlated (r= -0.8) with yield, grain weight, and plant stands. However, they were positively related with shriveled seeds (Table 4.6). In addition, shriveled seeds were negatively correlated with plant stands (r = -0.6), grain weight (r = -0.8) and yield per hectare (r = -0.7) but no significant relation with grain per cob (r =- 0.03), number of plants per metre square (r = -0.3) and seed emergence (r = -0.5). Beside these, seed emergence was not significantly correlated (r= -) with all the tested parameters except yield per hectare (r = 0.5) Table 4.7.

Table4.7. Correlation coefficients between mean seed quality parameters and agronomic traits of maize seeds from five agro-ecological zones of Ghana planted in the 2015 minor season at knust.

	PS	*BS*	*DS*	*PDS*	*SS*	*SE*	*PP*	*PLS*	*G/C*	*GWT*	*Y/ha*
PS											
BS	-0.892**										
DS	-0.935**	0.794**									
PDS	-0.912**	0.723**	0.842**								
SS	-0.917**	0.742**	0.779**	0.810**							
SE	0.563**	-0.598**	-0.503*	-0.454^{NS}	-0.496**						
PP	0.313^{NS}	-0.313^{NS}	-0.296^{NS}	-0.274^{NS}	-0.266^{NS}	0.164^{NS}					
PLS	0.629**	-0.466**	-0.564**	-0.622**	-0.651*	0.525**	0.073^{NS}				
G/C	-0.172^{NS}	0.319^{NS}	0.173^{NS}	0.118^{NS}	0.032^{NS}	-0.168^{NS}	0.094^{NS}	-0.262^{NS}			
GWT	0.876**	-0.693**	-0.780**	-0.836**	-0.889**	0.349^{NS}	-0.038^{NS}	0.483**	-0.206^{NS}		
Y/ha	0.737**	-0.630**	-0.649**	-0.722**	-0.702**	0.526*	0.073^{NS}	0.612**	-0.252^{NS}	0.563*	

Where, PS= pure seeds, BS= broken seeds, DS= discoloured seeds, PDS= pest damaged seeds, SS= shrivelled seeds, SE= seed emergence, PP= plant population, PLS= plant sands, G/C= grain per cob, GWT= 100 seed grain weight, Y/ha= grain yield per hectare in kg, NS, * and**=non-significant, significantly different at 5 % and 1 % respectively.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Purity analysis of certified and farmer-saved maize seeds

5.1.1 Seed moisture content

At harvest, moisture content of seeds is usually high above 18% but due to various forms of drying, it can drop to 13% or less (Bewley *et al.*, 2013). The moisture content of seed samples under the farmer-saved seeds was high compared with seeds under certified seeds across the study zones. Under the farmer-saved grower system, maximum moisture content was at the Semideciduous zone and the minimum from the Guinea Savannah and Coastal Savannah zones. But under the certified seed grower system maximum and minimum recordings were at the Guinea Savannah and Semi-deciduous zone, respectively. It has been indicated that a number of factors, operative before, during and after harvest can affect moisture of the seeds. For the farmer-saved seeds, farmers used traditional practices to check the dryness of their maize seed usually by cracking /biting with their teeth. These techniques are not accurate, and therefore, harvested seed may still have high moisture content (Akowuah *et al.*, 2015). According to Jiang *et al.* (2013), through growth, maturation and ripening, the water content of seeds slowly decreases until harvested seeds finally dry to the point where there is no more drop in moisture because their water content reaches equilibrium with the ambient relative humidity. Seed moisture is the most significant factor in keeping viability during storage; it is the primary control of all activities in the seeds. Metabolic rate can be reduced by keeping seeds at safe moisture content levels increases (Gasparin *et al.*, 2013). The rate of deterioration rises as the seed moisture content rises (FORGHANI and MAROUF, 2015). Justice and Bass (1978) reported that if the seeds are kept at higher moisture content (12-14% mc) losses could be very fast due to mould growth on and in the seed or due to heating (18-20% mc). Moreover, biological activity of seeds, insects and moulds further intensification as the temperature increases. The higher the moisture content of the seeds, the more they are unfavorably affected by both upper and lower ranges of temperature (Dogbe *et al.*, 2014). It is important to note that very low moisture content (below 4%) may also damage seeds due to distraction of internal membranes, or cause hardening in some kinds of seed (Bewley *et al.*, 2013). However, some reports stated that the result difference in chemical composition of the seed caused by different climatic conditions and cultural practices during seed development and maturation, drying methods, storage conditions and the length of storage (McCormark, 2004).

5.1.2 Pure seeds

Seed purity is determined by the quantity of unwanted material existing in pure seed. Impurities such as noxious weed seed, unwanted crop seed or inert matter. The results of pure seeds per 1000g under certified seed systems recorded the maximum percentage than farmer-saved seeds across the study zones. The certified seed systems maintained higher seed purity than farmersaved seeds. Bishaw *et al*. (2012) reported that seed from the certified seed systems were better in quality than farmer-saved seeds. Setimela *et al.* (2016) and Baltazar *et al.* (2015) also reported that seeds produced under certified seed system were better in quality compared to farmer-saved seed system. Plant breeders try to create significant improvements in developing high yielding, adaptable, and disease free crops. These advances however, are not recognized until an efficient seed production system is in place that produces genetically superior varieties and makes them accessible to the farmers. Successful seed production requires seed to be genetically pure, free of admixture, and able to form uniform stand (McDonald and Copeland, 2012). According to Odongo *et al.* (2016), farmer-saved seeds were more contaminated due to improper handling and storage.

5.1.3 Broken (cracked) seeds

Another factor to consider that cause damage to seed during harvesting, shelling and conditioning are cracks. Seeds with their high moisture content are potentially very susceptible to damage. The study realized that the highest broken seed was recorded under farmer-saved seeds across the zones. Farmers do not consider seed moisture content level during harvesting. McDonald and Copeland (2012) showed that cracked seeds do not store well as integral seeds and that fungi enter the seed through cracks in the seed coat. Minor and unseen wounds in seeds, with discolorations, may not cause immediate loss in viability, but can be progressively serious with age of the seed. Ning *et al.* (2014) also reported similar results for soybean. According to Aydinsakir *et al.* (2013), techniques of harvesting, receiving the seeds during drying, shelling, handling and storing are the dangerous periods in the production of quality seed of maize. Drying should do on the cob, before threshing, since threshing causes cracks on seeds with high moisture content levels (Powell, 2009).

5.1.4 Discoloured seeds

Discoloured seeds are seeds which change their normal colour to red, smudge or black point/dark smudge as a result of pathogen infections (Fernandez *et al.*, 2014). Heavily discoloured seeds were with water soaked, symptoms and on bisecting such seeds, the embryo and endosperm showed necrosis and browning (Fernandez *et al.*, 2014). Discoloured seed had developed stages of contamination by *Fusarium* spp. and *Phaeoisariopis* spp. than the non-discoloured seed (Dube *et al.*, 2014). The result of this study showed the highest percentages of discoloured seeds observed under farmer-saved seeds compared to certified seed systems. Exposure to increasing periods of high temperature during seed filling and high humidity can expose seeds to pathogen infections (Egli *et al.*, 2005). Farmers do not harvest their maize at exact maturity time, this is also one factor to expose seeds to fungus development and then the fungus-infected seeds become highly discoloured (Jiang *et al.*, 2013).

5.1.5 Pest-damaged seeds

The study found the farmer-saved seeds to be highly infested by weevils than certified seeds. Those pest infested farmer-saved seeds also showed lower performance during germination test. Productivity of maize crop is affected due to the occurrence of post-harvest pests (Oerke, 2006). However, pesticide use has allowed farmers to modify production systems and to raise crop productivity despite to the negative effect of pests (Oerke, 2006). According to Kauth *et al.*, (2015), storage pests are major constraints in the maize seed, with losses of about 30%.

5.1.6 Shriveled maize seeds

The mean shriveled maize seeds between certified and farmer-saved seeds showed, there was significant difference across the study zones. This result has come from the type of soil, nutrient conditions, location of production, and incidence of diseases in the area of production, agronomic practices and moisture deficiency. Delayed maturity due to environmental and disease stresses pushed the plant to early maturity causing shriveled seeds (Asfaw *et al.*, 2013). Drought has effect on seedling growth and ear development of maize (Gao *et al.*, 2014). During initial phases of maize growth, water shortage affects plant biomass, and leaf photosynthetic capability. Eventually preventing the development of reproductive organs and dropping the size of the grains (Asakura *et al.*, 2012). Moisture stress, high temperature and nutrient deficiency during seed filling result in forced maturity.

5.2 Germination tests of maize seeds

5.2.1 Normal seedlings

The germination test is the determination of the development features of seed (Bradbeer, 2013).
A normal seedling has all of the essential structures present for normal growth (Gampala *et al.*, 2014). The maize seed germination done in the Plant Pathology laboratory revealed that, seed from certified seed system recorded the highest percentage normal seedlings compared with farmer-saved seeds. The seed germination observed within and across the zones indicated that within the zones, both seed production systems for the Guinea Savannah zone gave a good seed germination percentage of 93.9 (certified seed) and 83.3 (farmer saved seed). The mean percentages recorded across the zones showed significant differences ($p<0.05$) between the seed samples from each seed production system where the certified seed out-performed the farmer saved seed. This variation may be due to difference in climate, location of production, mechanical or internal physiological barriers, and management practices during production (Khan *et al.*, 2015). Lehmann and Joseph (2015) also reported that farmer-saved seeds recorded lower germination percentage, as observed in this present study.

5.2.2 Abnormal seedlings

The farmer-saved seeds recorded the highest abnormal seedling percentage compared to certified seed systems in all the study zones. Abnormal seedling is characterized as such because it is missing in one or more of its essential seedling structures such as the root, the shoot or both. Abnormalities may be caused by mechanical damage, pre-harvest desiccation and chemical damage (Kar *et al.*, 2014). According to Melo *et al.* (2015), mechanically damaged seed will result in seedlings that have no roots or shoots. This is caused by threshing the seed when it is too dry. There is evidence

(Keawkham *et al.*, 2014) that pre-harvest desiccations on any crop seeds that have not evenly matured also create abnormal seedlings.

5.2.3 Dead seeds

The results on the dead maize seeds from the five agro-ecological zones of Ghana indicated that the farmer-saved seed system produced more dead seeds than the certified seed system across the zones. However, there was no significant variation ($p>0.05$) between farmer-saved seeds across the study zones. Farmers neither store nor treat their seeds well though the seeds may be put in polypropylene bags, jute sacks or hung on trees near their house. These practices expose the seeds to re-wetting, pest and fungal diseases as a results the moisture contents increase and metabolic activities increase inside the seeds, leading to the death of the embryo (Akowuah *et al.*, 2015).

5.2.4 Ungerminated seeds

In comparison, the highest percentage of ungerminated seeds was recorded under farmer-saved seed systems than in certified seed systems. Seed germination is influenced by several biotic and abiotic factors that may include; adverse temperature, humidity, seed moisture content, presence of fungi, storage conditions and long periods of storage. The percentage seed germination observed within and across the zones indicated that; within the zones, both seed production systems for the Guinea Savannah zone gave a good seed germination percentage. The average percentage recorded across the zones showed significant differences ($p<0.05$) between the seed samples from each seed production system.

5.2.5 One hundred seed grain weight

There is evidence that the heavier seed grain give better seedling emergence, vigorous seedlings and high optimal stands leading to substantial yield increased when heavier seeds were compared to lighter seeds from the same lot (Dayal *et al.*, 2014). The mean 100 grain weights under certified and farmer-saved system indicated that, there was a significant difference ($p<0.05$) between the two seed systems across the ecological zones. The certified seed system 100 seed grain weight for the Rainforest zone was found to be heavier than those from the Transitional, Semi-deciduous, Coastal Savannah and Guinea Savannah zones. Sulewska *et al*. (2014) reported that, seed size plays a key role in the process of germination and it is commonly related with seedling vigour, which is very important for future crop plants. The heavier the 100 seed grain weight the better its performance during germination (Sulewska *et al*., 2014).

5.3 Identification of fungi associated with maize seeds

5.3.1 Aspergillius flavus

The incidence of *A. flavus* was recorded in all the study zones in certified and farmer-saved seed systems. The infection was generally higher in the farmer-saved seed system. Guinea Savannah zone had the highest value followed by Coastal Savannah, Semi-deciduous, Transitional, and then Rainforest zones (Table 4.2). *A. flavus* is present in the soil and contaminate the crops on the field when planted (Abe *et al.*, 2015). Maize grains are vulnerable to contamination by *A. flavus*, Fisher *et al.* (1992) reported that fungus distribution is higher on maize seeds than other crops.

5.3.2 Aspergillius niger

Aspergillius niger recorded the highest infection under certified seed systems indicate that, the farmer-saved seeds infections were as follows in highest to lowest, Rainforest zone, followed by Transitional, Guinea Savannah, Coastal Savannah, and Semi-deciduous zone (Gnonlonfin *et al.*, 2013).

5.3.3 *Colletotrichum* species

Farmer-saved seeds from the Rainforest zone had the highest infectious followed by Guinea Savannah zone. The Semi-deciduous, Coastal Savannah and Transitional zones recorded the infection value shown in Table 4.2, the infection was observed under certified seed system across the zones in lower incidence compared to farmer-saved seeds (Tao *et al.*, 2013).

5.3.4 *Penicillium* species

This fungus was also found in both the certified and farmer-saved seed systems across the study zones, but the highest infection was observed in farmer-saved seed system. Under certified seed system, the Guinea Savannah zone had the highest, Transitional and Semi-deciduous zones recorded the same value whereas Coastal Savannah and Rainforest zone also the same amount of infection incidence (Cao *et al.*, 2013) Table 4.2.

5.3.5 *Curvularia* species

Curvularia sp. was observed in Transitional zone in both seed systems, with 7% in the certified seed system and 3% in the farmer-saved seeds. In Semi-deciduous, Guinea Savannah, and Coastal Savannah zones it was found only on certified seed system. There is evidence different environmental factors exposure on seeds during production can cause damage to seed (Degraeve *et al.,* 2016).

5.4 Location of fungus on maize seeds components

5.4.1 Cotlyedons

The identification of fungi location in maize seed shows that, the fungus was found in cotyledon under certified and farmer-saved seed systems across all zones. The results shown in Table 4.2 *A. niger* infection was highest in farmer-saved seed system in Transitional zone (67%), followed by Semi-deciduous (53%) in certified seed system. Most of the seed-borne fungus infected the embryo through the flower or from the peduncle of the infected mother plant and the infected or contaminated pollen (Nome *et al.*, 2002). This may occur due to increasing kernel injury by pests that favour fungal development and to the incidence of stress conditions (Williams *et al.*, 2012). According to Shu *et al.* (2015) fungus colonize all tissues of maize seeds that produced under stress conditions than those produced in better environmental conditions. Hruska *et al.* (2015) also supported this idea.

5.4.2 Embryo

About 85% of embryonic seed borne-diseases are caused by fungi(Fry, 2012), *Colletotrichum* species was observed in the higher infection level in the embryo of the maize seeds evaluated under certified and farmer-saved seed systems from the five agro-ecological zones of Ghana. Except the Transitional zone under the farmer-saved, the Guinea Savannah (CS) and Rainforest (FS) had similar percent infection and also the semi-deciduous (CS) and Rainforest (CS) recorded similar. According to Naik *et al.* (2014), *Colletotrichum* species was found in maize kernels that was harvested with higher moisture content (Table 4.2).

5.4.3 Endosperms

Table 4.2 shows that *Aspergillius niger* infection recorded the highest percent incidence in endosperms of the seeds than cotyledon and embryo. Most of the seed-borne fungi reached and infected the endosperm through the flower or from the peduncle of the infected mother plant and the infected or contaminated pollen (Nome *et al.*, 2002). This may have happed due to increasing kernel damage by insects that favour fungal development and the occurrence of stress conditions(Williams *et al.*, 2012).

5.5 Field evaluation of the maize seed samples on phenological and growth parameters

5.5.1 Seed emergence

The mean seed emergence percentage counted after two weeks of planting, from the five agroecological zones of Ghana planted in 2015 minor season indicated that seeds from certified seed growers had uniform seedling emergence than farmers-saved seeds across all ecological zones. However, there was significant difference ($p<0.05$) between the certified and farmer-saved seeds

(Table 4.5). This is because of the difference of management practices during seed production. Farmers are not aware of seed moisture content, physiological maturity, seed treatments, and storage (Dubale *et al.*, 2014). According to Ukeh *et al.* (2012), maize seeds stored traditionally by farmers showed poor germination compared to certified seeds during field emergence.

5.5.2 Plant growth rate analysis

The results from growth analysis of the seed maize under certified and farmer-saved seed systems at 20, 40, 40, 80, and 100 days after planting showed that, there were variations in plant growth rate under both seed systems across the zones. The plant growth analysis at 20 days after planting showed that, there was significant difference between certified and farmer-saved seed systems between the zones. However, there was no variation within certified seeds between the agro-ecological zones. However, the variation declined after 60 DAP in both seed systems. At the early stage, the growth rate was slower compared to 40 and 60 DAP. The variation in seeds, biological activities, such as germination, emergence, vigour, and growth affect the quality of seed when seed is exposed to adverse weather condition during grain filling (Copeland and McDonald, 2012). The size of seeds can affect growth rate of the plant at early stages (Kraft *et al.*, 2015). The temperature could affect the metabolic reactions and growth. Turley *et al.* (2013) reported growth rate increased when temperature is high and slow at low temperature. The plant growth rate analysis 60 DAP showed that, there was growth rate difference between certified and farmer-saved seeds. Farmer-saved seeds from Transitional, Semi-deciduous and from Rainforest had recorded better results when compared with certified seeds from the same zone. The growth rate at 80DAP reduced compare to 20DAP, 40DAP, and 60DAP in both seed systems. Boyes *et al.* (2001) reported that maize plant growth rate gradually reduced after 20 weeks of planting. The growth rate at 100 DAP certified seed system, showed significant difference ($p<0.05$) across the zones except the Transitional zone, but under farmer-saved seed system, the Guinea Savannah and Semi-deciduous zones were significantly different ($p<0.05$) from Transitional, Coastal Savannah and Rainforest zones. According to Vessey (2002), at later stage, growth rates will subsequently decrease. Reynolds (2010) also reported maize plant growth rate gradually reduced after tasseling.

5.5.3 Plant girth measurement

The mean plant girth under certified seed system except the Rainforest zone, the Transitional, Guinea Savannah, Semi-deciduous, and Coastal Savannah zones was similar (15.8cm). Under farmer-saved seed system, the Transitional and Semi-deciduous zones showed similar (15.6cm) measurement. In addition Coastal Savannah and Rainforest zones also recorded similar (14.5cm) value. However, there was significant difference ($p<0.05$) between certified and farmer-saved seeds across the zones (Table 4.4). The application of organic and inorganic fertilizer could increase the plant girth, thicker stems, more green leaves per plant, and yields (Oad *et al.*, 2004).

5.5.4 Days to 50% tassel

The study revealed that the farmer-saved seed systems from all ecological zones took longer days to tassel. However, there was significant difference ($p<0.05$) between farmers-saved and certified seeds across the various ecological zones but there was no significant difference ($p>0.05$) within farmers-saved seeds across zones. Nevertheless, mean days to tasselling of the certified seed from Semi-deciduous and Coastal Savannah zones were significantly different ($p<0.05$) from Transitional but similar to that of Rainforest and Guinea savanna zone (Table 4.5). The variation was because of the ecological difference of the seed samples. However, Gray *et al.* (2011) reported there is no date difference in terms of tassel and maturity with in the same variety of maize. According to Anandhi (2016), growing days and change of temperature could change the growth and maturity of maize plants. Hayashi *et al.* (2015), also reported that days to maize plant tasselling was delay when temperature changed during tassel.

5.5.5 Days to 50 % silking

When compared the certified and farmer-saved seed systems from the five agro-ecological zones of Ghana, the certified seeds took shorter days to silk than farmer-saved seeds across the ecological zones. Although, there was significant difference ($p \leq 0.05$) between certified and farmers-saved seeds across the study zones, there was no significant difference ($p>0.05$) between the certified seed systems across zones, and also the farmers-saved seeds too (Table 4.5). This is also similar situations as mention in the case plant tassel above.

5.5.6 Days to physiological maturity

Physiological maturity showed there was significant difference ($p<0.05$) between certified and farmer-saved seeds across the ecological zones except the Coastal Savannah zone. Variation was also observed between certified seeds across the zones. In addition, there was difference in maturity dates between the farmer-saved seeds across the ecological zones (Table 4.5). The seed samples from farmer-saved seeds matured earlier than the certified seeds three to five days in average across the zones. The farmer-saved seeds were shriveled, smaller in weight compared to certified seeds, this shows that the seed endosperm had not fully developed during harvesting (De Vries *et al.*, 2015). Such type of seeds do not give good seedlings as a result they are shorter in height (Singh *et al.*, 2013). Ambika *et al.* (2014) reported that, the seed weight could affect the next plants physiology.

5.5.7 Maize kernels per cob

The mean kernels per cob analysis result displayed that, farmer-saved seeds from Semi-deciduous and Coastal Savannah zones recorded the highest value followed by the Guinea Savannah, Transitional, and Rainforest zones. There was significant difference ($p<0.05$) between the certified and farmer-saved seed systems across the agro-ecological zones. However, there was no significant difference ($p>0.05$) between certified seed system across the zones.

5.5.8 One hundred (100) seeds grain weight

It was realized that the certified and farmer-saved seeds from the Transitional and Guinea Savannah zones were significantly different ($p<0.05$) from that of certified and farmers-saved seeds from Coastal Savannah and Rainforest zones. There was no significant difference ($P>0.05$) between certified seed systems across the study zones. Research showed that large seeds were characterized by a higher field germination capacity, and generally seedlings had greater weight compared to those obtained from small seeds (Sulewska *et al.*, 2014)

5.5.9 Diseases found associated with of maize plants

Maize streak disease was observed on some plants under both seed systems (Figure 4.13A&B). The infection observed under farmer-saved seeds from Coastal Savannah was the highest and followed by Rainforest, Guinea Savannah, and Semi-deciduous zones, respectively. Under certified seed system Coastal Savannah and Rainforest zones recorded similar (1) ranking out of five scales, followed by Transitional zone. The disease symptoms were on the younger leaves six weeks after emergence. Shepherd *et al.* (2014) also reported streak virus disease symptom has shown from six to seven weeks after planting on maize. Maize streak virus which is endemic and devastate maize yields in sub-Saharan Africa including Ghana (Oppong *et al.*, 2015). Out breaks of the disease are often associated with drought conditions or irregular rains (Higashi *et al.*, 2013). Yield losses vary with time of infection and varietal resistance (Nair *et al.*, 2015).

5.5.10 Leaf dry weight

The result of leaf dry weight indicated that, there was significant difference ($p<0.05$) between certified and farmers-saved seeds across all agro-ecological zones. But there was no variation between farmer-saved seeds across ecological zones. However, except the certified seeds from Semi-deciduous zone, the Guinea Savannah has not shown significance between the Rainforest, Coastal Savannah and Transitional zones. The leaf of a plant is the most important part for preparing food for the plant (Earl and Davis, 2003). Plant senescence might decrease crop yield when it is encouraged by premature growth under adversarial environment (Gregersen *et al.*, 2013). Less leaf dry weight indicates less yield (Ashraf and Harris, 2013).

5.5.11 Cob dry weight

The cob dry weights from the certified seed system from all ecological zones were heavier than the farmers-saved seeds in the study zones. However, no significant difference ($p>0.05$) was recorded between certified seeds across the ecological zones. Under farmer-saved seeds, the Transitional, Guinea Savannah, Semi-deciduous, and Costal savanna zones had similar (663g) cob dry weight, but different from Rainforest zone (549g). According to Nemali *et al.* (2015) water deficiency during silking reduced the cob weight of maize.

5.5.12 Total plant dry weight

The maize above ground biomass could affect the quality of planting materials and locations (Graven and Carter, 1991). The mean of total plant dry weight in the study indicated that there was significant difference ($p<0.05$) between certified and farmer-saved seeds in the entire zones. There is evidence that climatic factor, air temperature, had the best relationships with variation in maize seed quality, that which affects to the next plantings (Liu *et al.*, 2013). Also some of the physical characteristics of seeds affect their vigour and as a result give lower yields (Sulewska *et al.*, 2014).

5.5.13 Evaluation of maize grain yield of certified and farmer-saved seeds

The experimental study on grain yield of certified and farmer-saved seeds from the five agroecological zones of Ghana revealed that, the certified seed systems gave higher yield than the farmer-saved seed systems across all zones. Under certified seed system, the Guinea Savannah zone recorded the largest yields, followed by Coastal Savannah, Rainforest, Semi-deciduous, and then the Transitional zones. Under farmer-saved seed system, the Guinea Savannah gave higher yields, followed by Coastal Savannah, Rainforest, and Transitional zones. There was significant difference ($p<0.05$) between certified and farmer-saved seeds across all the ecological zones. Sulewska *et al.* (2014) reported that, seed size plays a key role in the development of germination and it is typically associated with seedling vigour, which is very essential for future crop plants. Sulewska and Hanna (2014) also reported that seeds produced in different agro-ecological zones had yield variation. The observed difference may be attributed to moisture content, storage conditions and drying methods. Maize productivity is lower in Ghana compared with the potential yield of the crop. When compared, the yields of the certified and farmer-saved seed systems, the certified seed system had the largest yields. Ragasa *et al.* (2014) also reported that, certified seed system had higher yields compared to farmer-saved seed system.

5.6 Association of selected seed quality parameters, growth, maturity and yield traits

The correlation coefficient (r) showed positive significant association with yield per hectare, grain weight per plant stand, and seed emergence. However, negative significant relationship was found with broken, dead, pest damage and shriveled seeds, but no significant relation with number of plants per metre square and grains per cob. On the other hand, broken seed showed no significant association with the number of plants per metre square and plant stand. As observed from the correlation analysis, both dead and pest damaged seeds were not correlated with number of plants per metre square and grain per cob, but negatively correlated with yield, grain weight, and plant stands. Beside these, seed emergence was not significantly correlated with all the tested parameters except yield per hectare. Although there was no significant correlation between number of plants per unit area and plant stand, but there was significant correlation among grain per cob, grain weight and yields.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The result revealed significant difference between certified and farmer-saved seed systems on quality parameters; such as pure, broken, discoloured, pest-damaged, and shriveled seeds. The certified seed systems across all the study zones gave superior results than farmer-saved seeds in the tested parameters. Seed size played a major role in the germination and it is usually associated with seedling vigour, which is very important for future crop plants. The 100 seed weight observed in the study for certified seeds ranged between 27.1 and 30.4g whilst that for the farmer-saved seeds was between 23.7 and 25.4g. The purity analysis results showed that, seeds from certified seed system gave higher percent value than farmer-saved seed system, with Coastal Savannah recording 95.10%, Semi-deciduous (94.6%) Transitional (94.5%), Guinea Savannah (94.1%) and Rainforest zone (93.7%). In addition, the germination tests showed that, certified seed system recorded the highest normal seedlings across the study zones.

The percentage seed germination observed within and across the zones indicated that within the zones, both seed production systems for the Guinea Savannah zone gave good seed germination percentages of 93.9 (certified seed) and 83.3 (farmer saved seed). It was quite clear that there was significant difference among both seed systems. The difference observed may be as a result of the mother plant management during production, harvesting maturity, and moisture content, injuries incurred during harvesting, handling and processing. The relationship analysis showed significant association of yield components with seed quality parameters. The maximum mean yield was from certified seed from the Guinea Savannah zone (664kg/ha) and the minimum was observed in farmer-saved seeds from the Transitional zone (390.5kg/ha). The study revealed that seed quality parameters had impact on emergence, growth, and grain yields of maize. This confirms that, the seeds under farmer-saved seed system had lower quality in all tested parameters compared to certified seed system. The variations between the two seed systems are because farmers produce their seeds traditionally, which does not follow seed production techniques. Sustaining seed and seed quality in rigorous cropping systems for advanced yields and better quality grain production can be attained through optimal use of better-quality seeds.

Thus, information on seed quality parameters is very important to produce and practical crop production.

6.2 Recommendations

- To maintain optimal plant population and increase maize yield, certified seeds should be available to the farmers.
- Farmers should sort seed impurities before planting.
- And also strengthen farmers' capacity in seed production and postharvest handling of the seeds.
- However, further study of the variety across different locations and under farmer conditions are recommended.

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