KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI COLLEGE OF AGRICULTURE AND NATURAL RESOURCES FACULTY OF AGRICULTURE, DEPARTMENT OF HORTICULTURE

EFFECTS OF STORAGE MATERIAL ON THE SEED QUALITY CHARACTERISTICS OF FOUR RICE VARIETIES IN GHANA

BY

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CHARACTERISTICS OF FOUR RICE VARIETIES IN GHANA

BY

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A Thesis Submitted to the Department of Horticulture, Faculty of Agriculture of the College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in partial fulfilment of the requirement for the award of Master of Philosophy (MPhil) Seed Science and Technology

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DECLARATION

I hereby declare that this submission is the result of my own work and that it has not been submitted either in part or whole for any other degree elsewhere. Works by other authors have been duly acknowledged.

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DEDICATION

I dedicate this work to my parents Mr. and Mrs Awuni Yaaba who have sacrificed everything to give me the best education and also to Prof. Richard Akromah for the opportunity given to me to obtain this Master's degree and his unflinching support throughout my program.

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ABSTRACT

A field survey and seed storage experiment on farmer-saved seeds was carried out to determine the type of storage materials commonly used by farmers and their effect on the rate of deterioration. Rice varieties were collected from three rice growing districts in the Northern region of Ghana in December, 2014 season. The seed storage experiment was set up in a 4x4 factorial experiment (varieties x storage materials) arranged in a completely randomised design with four replications under ambient conditions in a laboratory. Rice seeds were evaluated before storage and after storage for physical purity, moisture content, germination percent, germination speed and electrical conductivity. The result showed that (36.7%) of farmers harvested rice 8-14 days after physiological maturity and 88% of them threshed their seeds by beating with sticks either on bare ground or on tarpaulin. Majority of the farmers stored seeds in woven nylon (47%) and jute (29%) sacks. Jasmine-85 packaged in woven unlined nylon sack had the higher moisture content (12.5% and Gomba the least (10.4%). Seeds stored in unlined nylon sack had higher moisture content (12.5%) than seeds stored in lined nylon sack (11.4%). Seeds stored in unlined jute and unlined nylon sacks had higher germination percentage (64.9% and 64.8%) respectively whiles lined nylon sacks had lower germination percentage (60.8%). Seeds stored in unlined nylon sacks recorded the highest germination speed (51.38 seedlings day^{-1}) and conductivity values (21.82 µS cm^{-1}g^{-1}). The study also showed that the type of storage material did not affect the seed vigour of the varieties after the 3 months of storage. GR18 recorded a higher number of *Prostephanus truncates* and *Tribolium casteneum* insects while Digang had the least infestation by both insects. The study concluded that unlined nylon sack was a better storage material with regard to seed quality attributes of the rice varieties.

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CHAPTER ONE

1.0 INTRODUCTION

Rice belongs to the genus *Oryza* of the family Poaceae. It contains 22 species, of which 20 are wild species and two, *Oryza sativa* and *Oryza glaberrima*, are cultivated. *Oryza sativa* is the most widely grown of the two cultivated species (Vaughan *et al*., 2003). Rice is the staple food for half of the world's population and the second most important crop in the world after wheat, with more than 98% currently grown in Asia (USDA, 2012).

It is also considered as one of the staple crops consumed daily in most homes in Ghana. Besides the one-third production input by local rice farmers in Ghana, government spends about 500 million dollars to import the remaining two thirds to meet the country's requirement annually. This situation has been attributed to the use of low quality seed despite the increase in production land acreage (Akowuah *et al.*, 2012).

The problem is further compounded by the fact that very few improved varieties of rice are available for the vast upland ecosystem available for rice production (DfID, 2000). Consequently, quality seed supply is limited, and this therefore compels the farmers to use their saved seeds for subsequent plantings (Marfo *et al*., 2000). A cold storage facility for seed storage is very expensive in Ghana and as such farmers store their seeds, irrespective of the source, under ambient conditions in different storage materials. Some of the popularly used storage materials are jute bags, polythene bags, clay pots, nylon fertilizer bags, etc. These materials accommodate the fluctuating temperature and relative humidity conditions of the ambient environment.

Such poorly stored seeds will therefore result in poor seed quality leading to poor stand establishment, low seedling vigour and low grain yield (Bam *et al.*, 2007). These seeds may also not be dried to the appropriate moisture content on the field before storage leading to rapid seed deterioration in storage (Bam *et al.*, 2007). To ensure that seeds stored by farmers maintain their quality for subsequent field establishment and good growth, there is the need to improve on the storage material used, if the storage conditions cannot be enhanced. The general objective of the study therefore was to determine the effects of different types of storage materials on the quality of farmers-saved seeds of rice. Specifically, the objectives were to:

1. identify the types of storage materials used for the storage of rice seeds;
2. determine the effects of different storage material on seed germination and vigour of four varieties of rice seed stored; and
3. determine the effects of different storage material on insect infestation of the four varieties under ambient storage conditions for three months.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Rice Taxonomy and Botany

Rice an annual grass, belongs to Oryza sativa L. of the gramineae family. It is a selfpollinated crop. There are twenty three species out of which two species are important cultivated species known for their commercial value namely, *Oryza sativa* and *Oryza glaberima* (Agropedia, 2009).

The Oryza *sativa* species is differentiated into three sub-species based on geographical conditions are *indica*, *japonica* and *javanica.* The variety *indica* refers to the tropical and sub-tropical varieties grown throughout South and South-East
Asia and Southern China. The variety *japonica* is grown in temperate areas of Japan,

China and Korea, while *javanica* varieties are grown alongside the *indicas* in Indonesia (Agropedia, 2009). Whereas *Oryza sativa* is grown in most parts of the Asian and American continents, *Oryza glaberima* is grown only in Africa (IRRI, 2002).

Rice (Oryza sativa) is a self-pollinating crop with both the male and female reproductive organs residing in the same flower but located differently. As a selfpollinating crop, the pollen produced by the plant fertilizes itself (Delimini, 2012). The rice seed which is produced consist of an embryo and endosperm enclosed by a bran layer and surrounded by a brown hull. The hull, consist of the palea, lemma, and rachilla. Germination of the rice seed is initiated when the temperature is adequate ($10^{O}C$ - $40^{O}C$) and moisture is present and any existing seed dormancy removed.

2.2 Origin and distribution of types of rice

2.2.1 African Rice (Oryza glaberrima Steud)

The origin, distribution, cultivation and diversification of the cultivated African rice species *Oryza glaberrima* Steud has some uniqueness to Africa and was domesticated in West Africa more than 3500 years ago. Related to the Asian species, *O. glaberrima* is uniquely characterized by its red hulls, small size, smooth glumes and tendency to break easily in during milling (Agnoun *et al*., 2012). This African rice type has been uniquely cultivated in Africa for a number of centuries which implies Africa has the potential of cultivating rice in terms of the ecology necessary in growing rice to feed herself (Agnoun *et al*., 2012).

The cultivation of the traditional local varieties under *Oryza glaberrima* continues to dominate in most of the agro-ecological zones of Ghana even though the yield is poor (Oteng, 1997). The African rice, is a source of a number of these traits which has competitive ability with weeds, anabling rice plants types which are more suited to smallholder conditions. *Oyza glaberrima* contrasts from O. sativa in numerous traits. The two species can be distinguished in the field by their ligule shape and panicle branching. *Oryza* glaberrima has important traits such as weed competitiveness, drought tolerance and ability to respond to low input conditions, resistant to pests and diseases, ability to grow in a wide range of difficult ecosystems such as rain fed and coastal mangrove areas. It also possess very competitive ability against weeds due to the early vigour of the seeds, low extinction, high light use efficiency, and high specific leaf area resulting to high canopy growth. It has droopy leaves which prevent sunshine from reaching the soil surface and further has high root biomass accumulation. The possession of these quality traits has enabled breeders to introgress traits from the *Oryza glaberrima* into *Oryza Sativa types producing* hybrid rice known as Nerica; New rice for Africa (Johnson, 2013; Sarla and Swamy, 2005).

2.2.2 Oryza sativa (Asian rice)

Rice (Oryza sativa L.) is important cereal in the world, with a global production of 590 million tons. It is an important staple crop in Ghana and in most countries (Adebisi *et al*., 2013). Asian rice (Oryza sativa) is a more recent introduction, possibly during the period of the Atlantic slave trade or earlier through trans-Saharan trade routes. Asian rice has two main subspecies: Oryza sativa var. japonica (shortgrained, mainly grown as upland rice) and O. sativa var. indica (long-grained, mainly a lowland type (Mokuwa *et al*., 2012).

Progenies of *Oryza glaberrima* and *O. sativa* subspecies *indica* are better adapted to rainfed and irrigated wetlands, while those of *O. glaberrima* and *O. sativa* subspecies *japonica* are more suited to rainfed dryland (Balasubramanian *et al*., 2007). The main rice types produced in Ghana are *Oryza sativa* and *Oryza Glaberima* and most upland rice farmers continue to grow traditional *Oryza. glaberrima* or old *Oryza sativa* varieties obtained from informal sources (Asante *et al*., 2013; ODI, 2003).

2.3 Rice Production in Ghana

Rice is produced in Ghana, which covers the entire major agro ecological zones, including the Interior Savannah zone, the High Rain Forest zone, Semi-deciduous rain forest zone and the Coastal Savannah zone. There are distinct agro-ecological ecosystem rice zones. Rainfed drylands, Rainfed lowlands or hydromorphic; Inland swamps and valley bottoms; and Irrigated paddies (Obeng, 1994) but the greatest rice potential lies in the Interior Savannah zone. This area covers almost the whole of the northern half of the country, extending over nearly 9.32 million hectares (Langyintuo and Dobge 2005). While rice is an important cash crop for small-to medium-scale farmers in some countries it is more of a subsistence crop in the Northern Region of Ghana where most of the rice is produced (Asamoah, 2012). The Northern region is the main producer with about 63 000 tonnes and produces about 38.38%, followed by Brong-Ahafo region; 28.27% and Volta region; 14.14% (USAID, 2009; FAO, 2006).

2.3.1 Women in small holder rice production in Ghana

In many West African countries including Ghana, women play a significant role in rice production, through which they earn enough to support their livelihood. For example, the Irrigation Development Authority in Ghana reported that women are engaged in both pre-harvest and post-harvest operations (Norman and Kebe, 2006).

Majority of the rice producers are males and women dominate the processing and marketing sectors. Women are mostly dominant in post-harvest practices such as threshing and traditional winnowing. In communities where women are involved in rice production which is a major source of livelihood, due to gender inequalities, women have less access to agricultural credit needed for investments in seed production although they have a better repayment reputation then men (USAID, 2009). This implies that women are more credit worthy hence should be given a higher platform to asses credit to increase rice seed production even though a lesser number of them are engaged in the production (Assuming-Brempong, 1998). In developing programs to gender-based gaps women should be given access to new technologies and resources. For instance if mechanization increases without increasing women's access to machinery and equipment, women could lose their major roles in tasks such as transplanting and threshing. Without the support of the above mentioned suggest that, lesser women will be involved in the aspect of large seed production their labor will be released by these technologies (USAID, 2009).

2.4 Importance of rice in Ghana

Rice is a food security crop. Food security has been defined as "access by all people at all times to enough food for an active healthy life". Food security at domestic level is also important for ensuring a good health. Rice is an important contributor to Ghana's food security. It is estimated that 840 million people in the world currently suffer from hunger and more than 50 percent live in areas where rice is vital for food, income and employment (Nguyen and Ferrero, 2006).

2.4.1 Nutritional importance of rice

Rice is the basic of the diet of many Sub Sahara people that provides substantial amount of dietary energy, it also contains proteins and is used mainly for human food. It provides more calories and protein than cassava, maize or sorghum or millet. In countries where rice is the staple food it plays a very important part in food security and socio-economic development (Norman and Kebe, 2006). Rice is a high energy calorie food which consists mainly of carbohydrate in the form of starch. The carbohydrate in rice constitute about 72-75 percent of the total grain composition. The protein of rice (glutelin/ oryzenin) content is around 7 percent. The nutritive value of rice protein (biological value = 80) is much higher than other cereals such as of wheat and maize (biological value = 60, 50), respectively. Rice contains minerals such as Thaimin, Riboflavin and Niacin which are mainly located in the pericarp and germ with about 4 percent phosphorus (Anon, 2011). Improved rice seed plays a role by alleviating poverty (Singh, 1990) and hence the availability of nutritious rice can help reduce hunger and malnourishment; especially children in Africa since many people depend on rice for food.

2.4.2 Economic importance of rice in Ghana

Rice is crucial to Ghana's economy and agriculture, accounting for nearly 15 percent of the total Gross Domestic Product (Assuming-Brempong, 1998). It covers 45 % of all area planted to cereals. This sector of agriculture provides employment for a lot of rural persons. However despite the provision of employment the importation of rice is estimated to account for more than 50 % of all rice consumed in the country (Berisavljevic, 2000).

Rice subsector also influences the movements in the exchange rate and has strong implications for the balance of payments. Rice is generally accepted as a medium of exchange and it drives the barter economy, it is often being used to procure coffee and cocoa, lure labour, and purchase farm inputs and wage goods. Ghana is recorded to have comparative advantage in the production of paddy rice over other countries in the sub-region (Assuming-Brempong, 1998). However, this advantage reduces as a result of high cost of processing and transportation systems and several other factors. By increasing rice yields through adequate supply of high vigorous seeds, introducing standard rice mills, storage facilities, drying patios and appropriate storage structures or warehouses, it is expected that the factors that influence the competitiveness will be addressed.

There have been several policy strategy measures targeted to reducing rice imports by 30% through increasing production levels to 370,000 tons per annum, increased mechanization, increased cultivation of upland and inland valleys, efficient utilization of existing irrigation, increased seed production and varietal improvement and utilization are all pursued to ensure food security in Ghana (MOFA, 2011).

The greatest rice potential lies in the Interior Savannah zone. This area covers almost the whole of the northern half of the country (Langyintuo and Dobge 2005). For a developing country like Ghana to gain self-sufficiency in rice production in the Savannah zone it is constrained and such major constraints is insufficient water.
Water is a major constraint in all the ecological zones except in the irrigated ecology. In the rainfed (dryland) ecology, water is a factor that dictates the failure or success of rice seed yields (Oteng, 1997). However there is the need for farmers to have high vigorous seeds that have high emergence rate to enable seedlings establish faster before onset of any long drought period. Farmers producing rice in the Northern rice producing districts in Karaga, Chereponi Salaga, Tolon and Kumbugu are abandoning rice cultivation due to the effect of climate change in Northern Ghana. The peak rain period is between August and September but this is not consistent due to drought and late rains leading to poor yield even with good agronomic practices. There are many farmers who are ignorant of the changing weather pattern and this affects the yield and quality of rice seed even in short storage duration periods (Oppong-Ansah, 2011).

2.5. Rice seed Production in Ghana

Rice forms a major part of the Ghanaian diet, locally grown rice is not patronized because of its variable quality. Several factors account for the variability in rice quality; including poor varietal purity and vigor (Tomlins *et al.*, 2005). These quality defects are as a result of poor planting materials, inappropriate post-harvest handling, and poor agronomic practices (Gayin *et al.*, 2009). Rice seed quality can be affected by variety, environment, and processing. The handling and the environment conditions during ripening, harvest, postharvest, and seed processing can enhance or impair quality. Yields of rice seed vary depending on many factors such as variety, seed type, threshing, drying, and storage condition and time. (Salif *et al.*, 2011). Certified seed production is in the hands of seed producers and companies. Seed production in Ghana is mostly rain-fed and male dominated (97%) with an average age of 50 years. Women however play very important roles in the seed system which is particularly at the processing centers. Women are hired to sort the seeds and they help in manual seed cleaning through physical removal of debris. Seed growers in Ghana are organized. And majority of the seed growers belong to Seed Producers Association of Ghana (SEEDPAG). The association offers a platform for addressing issues of concern and also offers capacity building services to seed growers and small scale farmers (Etwire *et al*, 2013). Farming success depends mainly, on the use of high quality seeds. For rice seeds in Ghana the minimum required for production and commercialization is 80%, regardless of the category (Marques *et al*., 2013).

Table 2.1: Current Rice Seed Production (MT)

Seed class	2012	2011	2010
Breeder seed	0.32	0.869	0.84
Foundation seed	14.1	14	23.5

Certified seed	2370.12	2,367.50	3,907.30

Source: CARD, A draft Rice Seed road map of Ghana (2014).

Although presently rice yields differ due to cropping types, the average yields are between 2.5 to 4.2 MT/Ha in the major season and 2.1 to 3.5 MT/Ha during the minor season compared to 9.8 MT/Ha for Egypt, 7 MT/Ha for the U.S. and Japan, and 4 MT/Ha for Vietnam. Considering the potential of improved varieties distributed by research institutions, Ghanaian yields are relatively low given the lack of access to quality seed, good storage materials and structures to keep the quality of the seeds for several months. It can be assumed that, given farmers access to these resources of which most practice indigenous ways of keeping the quality of seeds and the low level of production especially in rain fed rice, it is still promising to improve rice productivity and quality significantly at higher level of efficiency with timely and available distribution of quality seeds (USAID, 2009; Niangadom, 2010).

2.5.1 Seed distribution and Seed sale

The seed rate for rice is 80kg/ha and (CARD, 2014) and this rate has an influence on the seed yield depending on the variety. Seed growers have been producing various variety of seeds for sale. For seeds to be distributed, it is cleaned after harvesting, and packaged. Seed is mostly sold through agro-dealers (88.2%) and sometimes directly to farmers (5.1%). It is not unusual for some NGOs (6.7%) to purchase certified seeds and give it to farmers benefiting from their interventions. Seed is not usually sold on credit by seed growers to farmers (12.7%) and for that matter most farmers tend to keep their own seeds which may lose its vigour depending on the processing and storage method employed by the farmer (Etwire *et al.,* 2013). Most farmers (62%) processed their own seeds from the previous year's harvest while a few (10%) purchased seeds from market and extension agents. The rest of the farmers (28%) get their seeds from other sources namely; irrigation schemes and nearby countries (Asare, 2000 paper presentation).

2.5.2 Farmer saved seed

Generally, farmers obtain their seeds from various sources. Some of the seed is selected from grain they produce themselves; some is bought from (or exchanged with) neighboring families and some from certified seed, produced by seed companies which are bought in shops (ICRISAT, 2000).

Farmers' habitual use of various varieties of seeds from different sources is a way of ensuring against climatic changes or uncertainties. Notwithstanding long drought before the season begins, farmers need to preserve their varieties as a means of insuring available seeds that will maintain their viability against such climatic uncertainties.

The farmers' systems of seed supply form the most important source of seed in most farming systems of the world. The major part of agricultural land in the world is still sown with seed that is informally produced by farmers despite the replacement of large seed programs with farmers' seed system which is inadequate in the information and the education of the right practices of production and storage handling of seeds. In Ghana where a small survey in one area conducted, farmers who plant modern varieties recorded seed practices over a four-year period; showed that 75 percent of seed was farm-saved and the remaining 25 percent was obtained from the grain market or neighboring farmers; there were no instances of purchases from a seed dealer (Tripp and Mensah-Bonsu, 2013).

Therefore most farmers' sources of seed in Ghana are farmer saved. However these farmers unwillingness to purchase certified seeds from Seed dealers can be trained on producing their own seed, processing and storing of the seeds in the right available storage materials as well as in appropriate conditions of storage. There is the needs for a quicker attention in the local seed supply and holistically as a nation

(Conny, 2008). Due to the consistent use of the farmers' own seed as a result of unsubsidized and expensive certified seeds, the productivity and quality of seeds being planted by most farmers deteriorated due to inappropriate storage materials and knowledge of storage length of the varieties used. This creates a vicious cycle because reduced yields and quality from use of their own seed result in lower income, leaving less money to invest in the purchase of certified seed for the next crop (USAID report, 2009).

Rice is the crop for which there is substantial seed production is, apart from maize and it is currently the second leading seed crop but much of this seed is produced and distributed on behalf of projects rather than offered to farmers (Tripp and MensahBonsu, 2013). For a successful yield and uniform emergence and plant stand, the need to use high quality approved seeds is crucial in rice production. Hence standards have been set to obtain high quality seeds.

Table 2.2: Seed standards for rice in Ghana

Factor	Breeder	Foundation	Certified
% Varietal purity	99.9	99.9	99.7
% Minimum Specific purity	98	98	98
Germination %	80	80	80
Moisture content	12	12	12
Inert matter	2	2	2
Noxious weed seed	0	0	0
Other species	10 seeds/kg	10 seeds/kg	0.10 (%)
Minimum red rice	0	0	4seeds/kg

Source: MoFA Plant Protection and Regulatory Service Division.

2.6 Factors that affect seed quality

2.6.1 Weeds

In the tropics, rice is largely grown on small family lands, which are usually less than 4 ha and are grown in rain fed upland, rain fed lowland/hydromorphic, irrigated and seasonally deep flooded areas in West Africa. However weeds are one of the major biological constraints to production. In West Africa for instance upland rice comprises 57% (1.8 million ha) of the total rice area has a range of weeds which affect rice production seed, some of which include the grass weeds: *Digitaria* spp., *Echinochloa colona*, *Eleusine indica*, *Paspalum* spp., and *Rottboellia cochinchinensis*, and the broadleaf weeds: *Commelina* spp., *Ageratum conyzoides*, *Portulaca oleracea*, *Amaranthus spp.*

Upland rice, in particular, competes poorly with weeds and uncontrolled weeds often results in poor yield. In West Africa, yields of upland rice with farmers' weed control, were 44% lower than on researcher weeded plots (Johnson, 2013).

Weed infestation on lowland rice fields are usually caused by poor leveling, contaminated weed seeds and irrigation water however flooding the rice crop usually improves soil chemical conditions and anaerobic soil environment which prevents the germination and growth of many weeds.

Rice is not very competitive with weeds during the seedling stages, therefore vigorous seeds must be used for planting to avoid the early emergence of weeds which will suppress the emergence and quick growth and establishment of seedlings.

The most severe weeds and more widespread of lowland rice include sedges, such as *Cyperus difformis*, *Cyperus iria*, *Fimbristylis* spp. the grasses *Echinochloa crus-galli*, *E. crus-pavonis*, *E. glaberescens*, *E. pyramidalis*, *Ischaemum rugosum*, *Leptochloa* spp., *Oryza barthii*, *O. longistaminata*, *O. rufipogon* and the broadleaves *Ludwigia* spp., *Eclipta prostrata* and *Sphenochlea zeylanica*. The effect on seed quality is severe in seeds which are sown directly on lowland rice fields than in transplanted rice, as the rice and weed seedlings are similar in growth stage (Johnson, 2013).

The lack of weed competitiveness in modern varieties may be one reason that many upland rice farmers have retained traditional varieties. Hence there is the need for small scale rice farmers to keep these traditional rice varieties in appropriate local storage materials under ambient condition over long periods of time without fast deterioration of their seeds as well as a decline in the vigour.

2.6.2 Postharvest practices

Post-harvest practices includes, threshing, drying, cleaning and storage of the crop which vary from country to country and from farmer to farmer.

Rice harvesting is mainly carried out in Ghana manually. The process involves cutting of the rice plants at maturity stage, bulking, pre-drying, threshing, winnowing, drying and storage. A number of these post production activities have direct bearing on the quality of seed (Salif *et al*., 2011).

Several methods of harvesting are used in Ghana, depending on the type of rice ecology, size of field and the cultural practices of the ethnic group involved, or the production objectives that may be influenced by the operation cost. Improved methods of harvesting are mainly employed on big irrigated farms or lowland farms while the traditional methods are used on the upland fields, small irrigated farms and on undeveloped lowlands.

Manual harvesting is slow, time consuming, labour intensive and full of drudgery. As far as possible the harvested paddy should not be put on bare floor to avoid contamination with stones and mud and mould growth. This practice is very common with upland, small irrigated and underdeveloped lowland farmers in the Northern part of the country. Harvested paddy should be spread on plastic sheets, Tarpaulins or Traditional mats (Salif *et al*., 2011).

Harvesting methods that are mostly used in Ghana are Panicle and Sickle methods. The optimal stage to harvest a rice crop is when the grain moisture content is between 20-25% or when 80-85% of the grains are yellow straw coloured. Harvesting can be done 30 days after flowering. If the crop is harvested too late, many grains are lost through shattering or drying out and the seeds are cracked during threshing. Cracked seeds affects the embrayo which do not germinate. If rice is harvested too early, there will also be many immature seed grains and this will reduce the quality (Guisse, 2010).

The stage of harvesting seed crop at the appropriate stage is important to achieve high seed vigor. The optimum time for harvesting has been considered to be 30-42 days after heading in the wet season and 28-34 days after heading in the dry season (Krishnasamy and Seshu, 1990).

The Panicle harvesting provides less harvesting losses when compared to sickle harvesting even though sickle harvesting is much quicker and has the potential of saving time and labour cost (Guisse, 2010). Harvesting the seed crop at the appropriate stage of moisture content is important to obtain vigorous seeds. For each 5°C-rise in seed temperature, the life-span of the seed is halved. This rule of thumb, applies between 1 and 50 °C. The adverse effect of high temperature extends from physiological maturity to harvest (Chang, 1988).

2.6.3 Threshing

Threshing which occurs right after harvest is done to detach the grains from the panicles. Threshing methods widely used in the South of Ghana includes the "Bambam" and Bag beating methods. In these methods, sickle harvested rice panicles are beaten very hard against a large wooden box and the latter put in bags or sacks and beaten with big sticks to detach the grains from panicles. In the North of Ghana, harvested rice is put on the bare floor or on tapaulines and several labourers especially women are employed to beat with big sticks. Fissures or cracks may occur with continues beating which can affect the vigor and germinability by creating cracks on the seeds which further creates avenues for insects and pathogens.

Farmers with large acres of land sometimes use the machine in threshing (Guisse, 2010).

2.6.4 Drying

Some seeds must dry down to minimum moisture content before they can germinate. Low seed moisture content is a pre-requisite for long-term storage, and is the most important factor affecting longevity. Seeds lose viability and vigor during processing and storage mainly because of high seed moisture content (McCormack, 2004).

Seed drying is an important operation necessary for the storage quality of rice seed. It is done to reduce the moisture content to between 12% and about 14% depending on the predicted time of storage. High moisture content will encourage the growth of pathogens and less time of deterioration leading to low vigour of seeds consequently affecting the quality of rice seed. Rice seed dried for a long time in high sun intensity would develop fissures inside resulting to reduced quality in storage (Salif *et al*., 2011). Freshly harvested seed with moisture content exceeding 18%, can be dried effectively using forced ventilation of heated air, provided the flowing air does not go above 40 °C. Sun drying is a method also used for lowering the moisture content in rice but may cause radiation damage. It also requires frequent turning of the seeds in a pile for effective drying. Heated seed should be cooled in a dry atmosphere and quickly packaged to minimize moisture reabsorption. For the seed to loose moisture it requires that the Relative humidity of the air surrounding the seed should be lower than the equilibrium moisture content of the seed (Chang, 1988). The commonly drying method used by farmers includes sun drying. The crop is allowed to dry well in the sun before harvesting to avoid further drying of the rice seed.

The main reason why rice should be dried well is that rice contains a lot of moisture, there is active respiration causing a deterioration of the rice seed. Moisture enhances harmful insects and micro-organisms activities, causing rice to deteriorate. The germination rate of rice is lowered due to toxins that are produced by the growth of mould. Therefore, it is important to reduce moisture in rice seeds to prevent deterioration (Wimberly, 1983).

Rice grains should be dried to less than 14% moisture content as soon as possible after threshing. When seeds are to be stored for a longer period, they should be dried to 12% or less and preferably stored in a sealed container. Drying and tampering the grain a number of times or in stages during the drying process will maintain quality. This means drying the grain for a number of hours and allowing it to cool before drying it again. This process should be repeated at least a number of times until the grain reached 14% moisture content or less (Guisse, 2010).

2.7 Storage of Rice

Seeds need to have a good storage quality to ensure that it maintains conditions until it is used for sowing. During storage, quality can remain at the initial level or it may decline to a degree that will cause seed to be unacceptable for planting (Pratt *et al.,* 2009). Seed deterioration occurs during storage, leading to reduction of vigor, germination percent, and decreasing seedling growth rate. Temperature and moisture content are the important factors, which influence the viability of seeds during storage (Nemat Adly *et al*., 2011). However these factors can be controlled to reduce their effects on the rate of the seed deterioration in storage.

Seeds must be properly stored in order to maintain an acceptable level of germination and vigor until the time of planting. Depending on the storage period, the seeds can be planted the next season, or longer if the seeds are to be carried over for one or more seasons (Nemat Adly *et al*., 2011). Some seeds though look much alike differ considerably; some are short lived and others can be stored long periods (Gokhale, 2009). Similarly the genetic make - up of the varieties in the same kind influences the storability. Gokhale (2009) further mentioned that factors affecting seed longevity in storage includes the kind and variety of seed

Studies on different rice cultivars both of the glaberima and sativa groups with different harvesting stages and their storage potentials showed differences in longevity among the *O* sativa cultivars as well as the Oryza glaberima (Kameswara and Jackson, 1997)

Many crops that are reproduced from seed, are in large quantities and it is important that seeds are produced and stored properly. The quality of rice seed and grain in tropical regions can be maintained for a short period of time in traditional storage systems. Poor drying techniques, insecure storage facilities, and very high relative humidity and temperature contribute to the development of mold, increased insect activity and faster respiration in stored grain all contribute to a reduction in seed quality during the storage period. In a tropical country like Ghana it is common for seeds to be re-dried during the storage period and pesticides applied to control insects and this can help preserved for 6 to 7 months prior to sowing. However the establishment rates are still poor often below 10% (Rickman and Aquino 2007).

2.7.1 Moisture content of seed before storage

The rice seed is hygroscopic, and seed moisture content will reach equilibrium with the ambient relative humidity (RH) and temperature (Harrington, 1972).

As rule of thumb, for every 2% increase in seed moisture content, the life of the seed is halved. This rule applies to a range between 5% and 14%. Harvesting the seed crop at the appropriate stage of moisture content is important to obtain vigorous seeds after storage. For each 5°C-rise in seed temperature, the life-span of the seed is halved. This rule of thumb, applies between 1°C and 50 °C. The adverse effect of high temperature extends from physiological maturity to harvest (Bosland, 1993).

Controlling the equilibrium moisture content of the seed during storage is the most important factor in maintaining a safe storage environment. As seed is hygroscopic it equilibrates with its surrounding environment, and the atmospheric conditions will cause seed to equilibrate at moisture levels above 14% during the dry season and 15.5% during the wet season. Management practices used by most farmers include; drying grain to 10-12% using in-store drying or re-drying grain during storage; or drying the seed to a safe level and then sealing the seed from the outside environment and hope that the re-absorption of moisture during the wet season will be slow (Rickman and Aquino 2007). Free fatty acid content and free radicals are also the main causes of seed ageing and deterioration while in storage (Iqbal *et al*., 2002). Free fatty acid can damage lipid bilayer especially of mitochondria leading to reduce energy production which affects the germination speed of seeds (Booth and Bai, 1999).

Seed Quality Results from studies in all of the countries have shown that seed stored in hermetic storage conditions have a much longer viable life than seed stored under traditional systems (Rickman and Aquino 2007).

2.8 Seeds of Rice varieties stored by farmers

The seed rate for rice is 80kg/ha and there are 13 officially released rice varieties. (CARD, 2014) and these varieties when released are kept by farmers which are reused continually after harvesting over the years. Farmers often use seeds that have impurities and contaminants and are infected with pathogens which affects the potential viability of seeds during storage (Fujisaka *et al*., 1993). Jasmine 85 is the most popular aromatic rice variety which gained an increased popularity and it is widely grown in Ghana due to its popularity in appearance, cooking quality and high aroma level. Other varieties released by Savannah Agricultural Research institutes (CSIR-SARI) for rice farmers in the Northern part of Ghana includes Sari Rice 1 "Digang" meaning new rice, GR 18 (Afife), Nabogo rice, Katanga rice and Mashall (Dogbe, 2010). The management of rice seed after harvesting has been reported to play an `essential role following rice seed yield and quality (Daniels *et al*., 1998; Pearce *et al*., 2001).

2.9 Seed storage materials that affect seed quality

Many farmers are becoming aware of using suitable moisture- barrier containers in order to save time and expenses for storing seeds and germplasm. The seeds which are carried over to the second planting season need to be dried and packaged in moisture barrier containers to prevent loss of viability and vigor (Justice and Bass, 1979).

There are a wide variety of materials that can be used to store rice seed for short-term storage. Most of these are non-rigid materials such as cotton, burlap, paper, and composite materials such as multi-wall paper and plastic film, or polyethylene bags. Materials used for short-term storage are generally porous. They sufficiently protect the seeds from mixing, but do not protect from moisture or loss of seed viability. Several of these materials are usually used for mechanically separating seed lots, and for transporting seed until the seed can be placed in environmentally controlled conditions for longer-term storage (McCormack, 2004).

For storing large quantities of seed, metal gallon cans fitted with a rubber gasketed lid and pressure ring are ideal for storing large seeds such as peas, beans, and corn. (McCormack, 2004). Traditional farmers do not use metal gallons with fitted rubber gasket due to its unavailability and also expensive to purchase. These farmers usually use locally produced storage containers such as jute sacks, clay pots, polyethylene bags and nylon sacks which are inexpensive and available. The use of a good storage material will preserve the viability of seeds over a long period of storage. However viability of seeds stored in these storage materials over a short period inversely can help determine the effect over a longer period. Some properties of a good material including the following can maintain seed quality during storage are: the storage material should be convenient to stack to allow free flow of air while in storage, it should be able to prevent spoilage during transit or storage, it should not be too porous to absorb much moisture in the storage place. It should be clean, it should be strong to avoid bursting (Anon, 2011). A more recent approach to storage with a classic storage material is the storage systems based on the hermetic principle using material termed as cocoons. Which allows safe storage by preventing insects and other aerobic organisms in the commodity or the commodity itself to generate increased CO_2 concentrations through respiration hence reducing the O_2.

Storage problems prevail more in the presence of adequate oxygen and temperature. This allows by promoting the growth of insect population and in the presence of high relative humidity also molds develop to cause quality deterioration. This results in an increase in free fatty acids (FFAs), rancidification of flavour and mycotoxins. These storage problems are eliminated through the toxic effect of a low oxygen or high Carbon (IV) oxide atmosphere produced through respiration processes.

The hermitic storage cocoons were designed for storage at the farmer cooperative and small trader level with 10 - 1000 tonnes capacity, small scale storage of small portable containers of 60 kg to 2 tonnes capacity and for quality preservation, insect control and prevention of condensation transport (Jonfia-Essien *et al*., (2010).

2.10 Effects of Ambient storage on seed quality

Farmers throughout in every country particularly farmers in developing world at hot or cold climate still store seeds under ambient environment. They may store in traditional storages like earthen pots, in pits or in a granary, or in modern or sophisticated storages either in bulk or in reasonably quantities (Sawant *et al*., 2012).

In Ghana the quality of rice varieties can be maintained for short periods of time in traditional storage materials and open storage systems. Several factors which contribute to the development of mould, increased insect activity and faster respiration in stored rice seed includes poor drying techniques, insecure storage materials and high relative humidity and temperature. Although the seed moisture content levels may be within the acceptable range the storage temperature and relative humidity still affects the viability of seeds (Rickman and Aquino, 2007).

During the harmattan period from December to March the humidity is relatively high (77% to 85%), causing hot days and cool nights. The fluctuating temperature and humid climatic condition is not suitable for the storage of rice for longer periods (Sawant *et al*. 2012). The temperatures in the Northern region varies from 29 ℃ to 35 ℃ and these fluctuating environmental factors have direct influence on the moisture content of the seed as well as the storability depending on the type of storage material used for the seeds in storage (Gattani, 2008). Primary aim of storage is simply to prevent deterioration of the quality of seed. This is done indirectly through the control of moisture and air movements, and through preventing attack of microorganisms, insects and rodents. In general storage for long or short term is improved under ambient humidity if the seed is well packaged (McCormack, 2004).

2.11 Effects of storage insect on rice quality

Loss in seed viability through the activity of insects in storage is one of the major problems faced by rice seed paddy producers and farmers. Therefore attention should be dedicated to retain viability of seed during storage. The type of packaging material is one of the factors that contribute to minimizing or enhancing insect activities on the seed in store. Weight loss in rice during storage can lead to reduction in vigor, abnormal seedling development which consequently lead to poor yield. Grain moth (*Sitotroga cerealella*), rice weevil (*Sitophilus oryzae*), red flour beetle (*Tribolium casteneum*) and *Prostephanus truncates* (Larger grain borer) are the most important storage pests of rice. However the packaging material used for storage have an influence on the population of these pest which eventually affects the quality (vigor) of the seeds (Dharmasena and Abeysiriwardena, 1995).

2.12 Seed quality

Seed quality refers to physical and genetical purity, free from disease and has a high germinability and vigour. It is very important to use quality seed in rice production. Using quality seed can increase your yield between 5 to 20 percent. Low quality seeds will introduce more weeds and off-types into your crop, make the crop more susceptible to disease, eventually producing plants that are weaker (IRRI, 2012).

2.13 Aspects of seed quality

2.13.1 Seed vigor

Vigour is an important seed quality factor different from germinability. Different seed samples may have the same germination but can have differences in their vigour (Delouche and Baskin, 1973). The International Seed Testing Association (ISTA) (2007) defines seed vigor as the sum of those properties that determine the activity and level of performance of seed lots of acceptable germination in a wide range of environments. It specifies some of the characteristics encompassed within the term vigor which are rate and uniformity of seed germination and seedling growth, emergence ability of seeds under unfavorable environmental conditions and performance after storage, mainly the retention of the ability to germinate.

Enhancing rice productivity is to ensure that quality seeds are used for sowing and since the seed is vulnerable to adverse weather conditions during ripening, harvest, and storage, farmers are often forced to sow poor quality seed, which results in inadequate seedling stand, hence poor yield. Krishnasamy and Seshu (1990) also added that seed vigor is the sum total of those properties of the seed that determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence.

According to McCormack (2004) also, seed vigor is defined by normal seedling morphology as the rate at which seeds germinate and grow in the early stages.

Early research and on farm production of rice seeds have shown that low germination and poor seedling establishment are among the problems being faced by the farmers. The relationship between vigor and viability is similar except that vigor reduces or drops before viability. (McCormack, 2004). The low seed vigour has been recognized as the factor mostly responsible for poor germination and uneven seedling establishment. It has been stated that a close relationship exist between seed vigour and seed yield. Distinct characteristics in seed vigour and seed yield identified includes; seed germination, speed of germination index, seedling vigour index, energy of germination, seedling emergence and seedling establishment as the most desirable seed vigour traits in the rice varieties (Okeola *et al*., 2007).

The performance of seeds as "high vigour'' or "low vigour' that may show variations is connected to differences in biochemical processes and reactions during germination such as enzyme rate and uniformity of seed germination and seedling growth, rate and uniformity of seedling emergence, growth in the field, and emergence ability of seedlings under unfavorable environmental conditions. There are many factors which induce variation in seed vigour level but the main causes include position of the seed on mother plant, the size and weight of seed, mechanical effect such as deterioration and natural ageing, seed processing methods, pathogen infection, seed treatment and genetic variability (Krishnasamy and Seshu 1990). Seed vigor indicates the fact that aging (natural and artificial) is mainly responsible for vigor differences (Proceedings of the Regional Technical Meeting on Seed policy, 2001). Seed vigour tests are done to provide a better prediction of seed performance in the field and it is important in seed production (Perry, 1981). The tests does not predict percentage of field emergence, but neither does standard germination. But rather vigour tests better relates to field emergence under stressful soil conditions than standard germination does (Tekrony and Spears, 2001). Several vigour test have been performed to predict seedling stand on the field; they include physiological test (standard germination, speed of germination, seedling evaluation, cold test, accelerated aging, controlled deterioration) physical test (seed size, weight, volume) Biochemical test (tetrazolium test, conductivity) (van-Gastel *et al.,* 1996).

As seed deterioration progresses, the cell membranes become less rigid and the more the seed become water-permeable. This causes the cell contents to escape into solution with the water and increasing its electrical conductivity. The test gives an accurate estimation of membrane permeability (ISTA, 2007).

2.13.2 Genetic purity

Genetic or varietal purity refers to whether a variety is true to type, meaning the seed possesses all the genetic qualities that breeder has placed in the variety and still has the original genetic make-up (van Gastel *et al*., 1996). Seed growers expect highquality, genetically pure seed. As a result, seed companies maintain quality control programs that monitor seed from harvest to purchase. A high level of genetic purity in crop varieties must be attained and maintained for agronomic performance as well as to encourage innovations in plant breeding so as to ensure that productivity and quality improvements by breeders are delivered to the farmers (Smith and Register, 1998; McDonald, 1997). Contamination of the genetic quality of a variety comes about mostly through gross admixtures, excessive mutations or pollination by undesirable pollen (FAO, 2010). The purity of a variety is best evaluated through a field trial in pre and post control test plots in which the percentage of off- types in seed lot is determined Elias *et al*., (2011). Genetic purity of seeds refers to the trueness to type, it is said to be genetically pure. The genetic purity affect yields eventually in that if there is any decline in the genetic make-up through pollen or other seed admixtures contamination of the variety during seed multiplication and distribution cycle, there would definitely be decrease in seed performance.

2.13.3 Physical purity

Physical purity or analytical purity is the proportion of pure seed in a lot and the composition of undesirable matter (van-Gastel *et al*., 1996). Seed physical purity test is the most fundamental and the first test to be carried out in seed testing, as the subsequent tests are made only on the pure seed component. Seed purity of a seed lot is based on physical determination of the components present and include percentage by weight of pure seeds (working sample represented by the crop species of which the lot is being tested), other crop seeds (seeds other than seed being tested), weed seeds (seed present from plants considered as weed) and inert mater consisting of materials which are not seed (Copeland and McDonald 2001).

Eskandari (2012) also describes physical purity by the minimum of damaged seed, (broken, cracked or shriveled) which can cause seed not to germinate and is more likely to be attacked by insects or micro-organisms. Minimal weed seed or inert matter, Minimum of diseased seed; discolored or stained seed may carry microorganisms that already have attacked or will attack the seed when it starts to grow and in cases where the plant survives can spread the disease to other plants.

2.13.4 Moisture content

The moisture content of a sample is the loss in weight when it is dried in accordance with rules. It is expressed as a percentage weight of the original sample (ISTA, 2007).

Moisture content is a quality parameter that has a crucial influence on storage and longevity. High moisture content stimulate the enzyme production, consequently assisting in breakdown of food storage in seeds, and this metabolic activity releases heat that will lead to fungal growth causing reduction in the viability of the seeds (Bennets and Cocks 1996). Therefore Karrfalt, (2001) stated that samples of seeds should be packed in waterproof material as quickly as possible in order to maintain the moisture within this packaging until the working sample for moisture content determination has been taken out.

2.13.5 Germination

Seed germination may be defined as a sequence of physiological events that occur before radicle protrusion in non-dormant soaked seeds, being the step that involves the establishment of seedlings, called the post-germination event. The physiological state of the seeds differs in the germination and post-germination processes due to gene expression and desiccation tolerance (Nonogaki, 2006).

Germination has also been defined as "the emergence and development from the seed embryo of those essential structures which, for the kind of seed tested indicate its ability to develop into a normal plant under favourable, conditions in soil" (Sweedman and Merritt, 2006).

For the germination of rice seed in aerated condition the radicle protrude out through the coleohiza followed by the emergence of the young shoot the coleoptile (Patin and Gutormson, 2005). During germination tests, the quality of the seed is measured directly as the ability of the seed to germinate under optimal germination conditions of temperature, moisture and light. It is anticipated that germination should not be impeded by dormancy hence seeds should be pretreated before a germination test.

At the initial stage of seedling growth, coleoptile and succeeding leaves growth is mainly dependent on the seed reserve in the endosperm Germination is normally carried out in germination cabinets under controlled environment or germination trays in the laboratory (Schmidt, 2000; Yoshida 1981)

Therefore in establishing a good relationship between quality rice seeds and field emergence through vigor test is way to predict the value and viability of the seeds in storage. While standard germination tests is not a good indicator for actual field emergence, there is a good correlation that exist between standard germination and field emergence (Ailoo and Shokati, 2011; Sulewska *et al*., 2009). Germination is an adaptive traits of plants which is influenced by a number of genes and environmental factors. Plant genetics and physiology have shown the significant roles of the plant hormones, abscisic acid and gibberellin in regulation of dormancy and germination (Koornneef *et al*., 2002).

2.14 Seedling vigour Methods

2.14.1 Seedling measurement

Seedling measurement is considered an important parameter in determining rice seedling vigour. Several researchers have found good relationship between seedling length and its dry weight with field emergence (Ching *et al*., 1977; Nayeem and Mahajan, 1991, Kim *et al*., 1994, Divsalar *et al*., 2013).

2.14.2 Germination speed index

Germination speed is a direct measure of vigor which is defined as the number of germinated seed per day. The higher GSI value, the faster the germination speed hence the higher the vigour (Husseine, 2012). The number of seedlings emerging daily are counted from day of planting the seeds in the medium till the time germination is complete.

2.14.3 Germination percentage

Germination test is an assessment of the ability of seed to germinate and emerge in the field and the number of germinated seedlings expressed as a percentage. Standard germination gives a good correlation between germination and field emergence in favorable conditions however germination can fail to indicate the ability of a seed lot to establish as a crop in poor field conditions (Proceedings of the Regional Technical Meeting on Seed, 2001). This failure of the germination test to predict differences in field emergence, suggested that there is a further physiological aspect to seed quality, which has come to be noted as seed vigor (ISTA, 1995). Differences in the vigor of germinable seed can be explained by the process of seed aging.

2.14.4 Size and weight

Mature medium and large-size seed will generally have higher germination and vigor than small and immature seed. In the conditioning (processing) of seed lot, undersized and light seed is normally eliminated (Eskandari, 2012).

Observations revealed that small seed sizes, produced significantly shorter seedlings than those produced from large seeds (Hussein *et al.* 2001).

2.14.5 Vigour tests

2.14.5.1 Accelerated Ageing

Accelerated ageing test is one of the most often used vigor testing method used for seeds. It is the most popular seed vigor test due to it is simplicity, and ease of standardization (Tekrony, 1995). The ISTA standardized this method for seed testing, however a uniform accelerated aging procedure has not been developed for testing rice. Studies of Leeks (2006) relating to seeds revealed a high correlation between germination obtained by using vigour test and field emergence (Miloševic *et al*., (2010); Woltz and Tekrony, (2001).

The principle of this method is based on artificially accelerating the deterioration rate of the seeds by exposing them to high temperature and relative humidity levels (Hussein *et al*., 2012). Among the vigour evaluation tests, the accelerated aging test has shown to define seeds vigour and, as a result, predict their storage potential. The storage potential is known, because it delays the germination process as well as the embryo's growth (Maia *et al*., 2007; Marcos-Filho, 2005). This test can also be used in order to evaluate the physiological potential of seeds after certain storage period (Panobianco *et al*., 2007).

It was initially developed as a test to predict the life span of a number of different species under various storage conditions. Accelerated aging is very effective in testing the relative storage potential of seed lot and used to determine the quality of seed lots.

Accelerated aging damages DNA and mRNA hence causes a biochemical deterioration of the stored material and reduces the vigor of seedling and seedling development just after germination. However, the process of accelerated aging conditions are essentially similar to those under normal conditions. The major differences is that the rate of deterioration is much faster hence the possibility to predict storage potential. In accelerated ageing test the seeds are exposed to tress condition of Relative humidity above 0 and high temperature levels (0-) over a short period (1-8 days) followed by regular germination test (Hussein *et.al*, 2012).

The technique involved the exposure of seeds to adverse levels of temperature (4045ºC) and 100% R.H. for varying length of time followed by regular germination test (Chhetri, 2009).

2.14.5.2 Seed electrical conductivity test

Standard minimum germination percentages are laid down for each species before it can be sold. This is to ensure a low failure of emergence of seeds sown by farmers. Although highly germinable seeds are sown, there may be differences in field emergence which is as a result of differences in seed lot vigour (Powell, 1986).

Vigour of a seed can be affected by mechanical damage to embryo or seed coat, environment and nutrition of the mother plant, stage of maturity at harvest, seed size, senescence, attack by pathogens and drying temperature can influence on the mechanical damage of the seeds (van-Gastel *et al.,* 1996). The rapid emergence of seeds in the field determines if the seed has a low vigour or high vigour. The detection of low vigour lots before sowing is very key to obtaining a high seedling stand and good seed yield. Seed conductivity test is one of the vigour test of seed quality which is based on the leaching of solutes from seeds into water. Although the Accelerated ageing test has been indicated to determine seed vigour and its storage potentiality, the electrical conductivity test has been used to evaluate the seeds vigor in several species for being simple to execute, of low cost, fast, replicable and with easy interpreting results (Vieira and Krzyzanowski, 1999). It detect the seeds deterioration rate during the storage period (Abreu *et al*., 2011; Panobianco *et al*., 2007).

Conductivity test is based on the principle that when seed deteriorates during storage the cell membranes become less rigid making it water-permeable, allowing the cell contents to leak into solution with the water causing an increasing in its electrical conductivity. Conductivity test provides an accurate estimation of membrane permeability (ISTA, 2007).

Seed lots having high electrolyte leakage, that is, having high leachate conductivity, are considered as having low vigour, whilst those with low leakage (low conductivity) are considered as having high vigour (ISTA, 2007). Procedure for conductivity test outlined by ISTA (2007) describes using four replicates of 50 seeds of each sample drawn at random and tested for electrical conductivity. The seeds are placed in Erlenmeyer flasks containing 75 ml ultra-pure deionized water equilibrated to 25 °C, then maintained at 25 °C for 24 h. After 24 h of soaking, the flasks was swirled for 10-15 sec and seeds then taken out of water with a clean forceps (ISTA, 2007).

An electrical conductivity dip cell is inserted into the seep water until a stabilized reading is achieved and recorded. The mean of the two control flasks (sterilized distilled water) when measured served as background reading. Conductivity is calculated using the formula below (ISTA, 2007).

$$\text{onductivity } (\mu S\ cm^{-1} g^{-1}) = \frac{\text{(Conductivity reading - background reading)}}{\text{(Weight (g) of replicate)}}$$

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted in six districts in the Northern region of Ghana which lies between latitude (5.50N, 7.46N) and longitude (0.15W and 2.25W). The region has an annual minimum mean temperature of 23°C and the mean annual rainfall is about

1034 -1100mm with the peak in August. Humidity is relatively between 20% -70 % Between October and March there is virtually no rain and this long dry season is made harsh by the dry North Eastern harmattan winds which affects the day time heat (FAO, 2006).

3.2 Scope of study

The study comprised a field survey and a laboratory storage experiment. The field survey was conducted in the Northern region while the laboratory experiment was carried out at the Department of Horticulture, KNUST, Kumasi.

3.2.1 Field survey

A field survey was conducted in Northern region in six rice growing communities, namely, Libi, Nakpanye (Gonja East district), Tolon (Tolon Kumbugu district) Woribogu and Worebogu Kokuo (Tolon district) and Dingoni (Savelugu Nanton District). The survey was from August to September, 2014 and the objective was to identify the different storage materials, seed production and processing methods and practices used by farmers in the storage of their rice seeds and how these storage practices affect the viability of their seeds. A semi-structured questionnaire was randomly administered to ten farmers from each community to gather the field information. Information gathered included sources of farmers' rice seeds, type of seeds, harvesting operations, how seeds were stored, type of storage container, problems of storage, and knowledge of farmers' storage system.

3.3 Collection and storage of rice seed samples

Sixteen kilograms each of four rice varieties (Gomba, Jasmine 85, Digang and GR 18) were collected from farmers one month after harvesting in November, 2014. A total of

64 kg of rice seeds were collected and kept in plain bags labelled, sealed, and stored under room temperature for one week before being transported to Kumasi.

The seeds were subjected to quality analysis at the Department of Horticulture, KNUST. One kilogram seed sample of each variety was weighed and stored in four different storage containers each measuring 30cm x 30cm. The four storage containers were woven Unlined Jute Sacks (UJS), Unlined Nylon Sacks (UNFS), Linned Jute Sacks (LJS) and Linned Nylon Sacks (LNFS). All treatments were replicated four times.

3.4 Characteristics of varieties used

GR 18 (Afife rice): It has a potential yield of 4-6.5 tons/hectare and matures in 120130 days. It has short round seeds.

Jasmine 85: It has a yield potential of 4.5-8 tons/hectare and matures in 110-120 days. The rice is aromatic, longer, and slender and has good taste preferred by consumers.

Digang: It has a yield potential of 4.5 tons/hectare and matures in 115-120 days. It is good for drought-prone areas. The grains break easily.

Gomba: A type of *Oryza glaberrima* specie of rice. African rice seedlings normally emerge in 4–5 days after sowing or more (6-10 days). African rice is self-fertilizing.

The maturity of the crop varies from 3-6 months depending on cultivar and type of culture

3.5 Seed Storage Experiment

The seed storage trial was set up in a 4 x 4 factorial arrangement in a completely randomized design. The first factor was varieties at four levels; Jasmine-85, Digang GR-18, Gomba while the second factor was storage materials at four levels; Unlined jute sacks (UJS), Unlined nylon sacks (UNFS), Lined jute sacks (LJS) and Lined nylon sacks (LNFS). The experiment was replicated four times and the treatments were stored under ambient room conditions for three months.

3.5.1 Data collection

3.5.1.1 Storage environmental conditions

Daily humidity and temperature readings were recorded for the storage room. A Lascar (Microdaq humidity and temperature data logger) was used to monitor the daily temperature and humidity in the storage room.

3.5.1.2 Moisture content

The seeds moisture content was taken before and after storage using the GANN Hydrometer G86 moisture meter. Seeds were placed in the cup and covered tightly and readings were taken 3 times consistently and the average taken as the moisture content of the rice sample in the cup (Alam *et al*., 2009).

3.5.1.3 Seed Purity Test

Purity analyses was conducted using 40 grams of impure seeds by separating the inert material including stones, weed seeds, chaff, twigs, sand and other seeds. The impurities were weighed and subtracted from the total weight of the impure seeds to obtain the pure seed.

3.5.1.4 Germination Test

The germination test of the seeds before and after storage was conducted at the Department of Horticulture. The test was done using sterilized sand as the substrate in asbestos germination trays of sizes 70 cm x 45 cm with 2 cm depth cells. Pure seeds were sown in 4 replicates with 100 seeds per replicate in the trays at the o temperature environment of 29 C and 60%-78% relative humidity for 14 days.

3.5.1.5 Germination speed index

Germinated seeds were observed daily from the first count until the final day of count. The germinated seedlings were evaluated and percent germination was expressed based on normal seedlings according to the International seed testing association, (ISTA, 2007). The germination speed index was then calculated using the formula below of the Association of Official Seed Analysts.

$$GSI = \frac{\text{No of germinated seed}}{\text{Days of first count}} + \ldots + \ldots + \frac{\text{No of germinated seed}}{\text{Days of final count}}$$

The germination speed parameter is derived by dividing daily the accumulated number of germinants by the corresponding number of days (Hossain *et al*., 2005).

3.5.1.6 Seed vigour (Electrical conductivity)

The electrical conductivity test was done before and after storage using pure seed fraction. Fifty seeds were counted and weighed into beakers. Seeds were soaked in 75ml of distilled water for 24 hours. Two control flasks (sterilized distilled water) was also measured into beakers and the electrical conductivity of the water measured. After soaking, the Eutech instrument PC 700 electrical conductivity meter dip cell was dipped in the seeped water and their conductivity taken at 25°C ± 1 and expressed in µS cm-1 g-1. The mean of the two control or blank distilled water when measured was used as the background readings and calculated using the formula below (ISTA, 2007).

$$\text{onductivity } (\mu S\ cm^{-1}g^{-1}) = \frac{\text{(Conductivity reading - background reading)}}{\text{(Weight (g) of replicate)}}$$

3.6 Seed health determination (Insects infestation and identification)

After the storage period, insects found in each treatment were identified and counted. This was done by emptying the entire seeds of each storage material in a sieve and sieved on a plain sheet. The type of insects found were identified under a light microscope.

3.7 Data Analyses

Data collected from the field survey was subjected to analyses using Social Science Statistical software (SPSS Version 10) and the seed storage experiment was analyzed using STATISTIX statistical tool version 10 and means separation at a probability level of 0.05.

CHAPTER FOUR

4.0 RESULTS

4.1 FIELD SURVEY STUDY

4.1.1 Gender of respondents

Seventy two percent (72%) are males and twenty eight (28%) percent were females as shown in Figure 4.1.

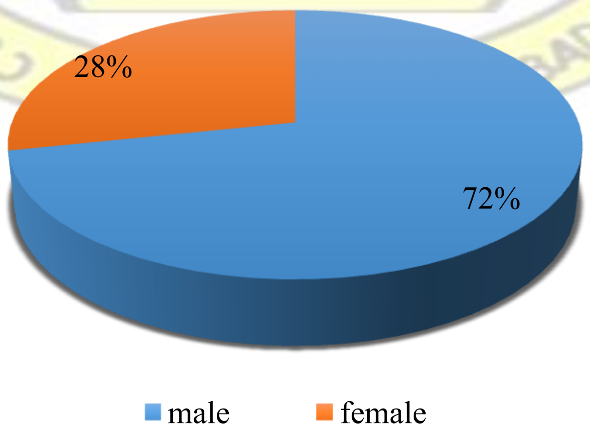

Figure 4.1: Gender analysis of the respondents

4.1.2 Time to harvesting of crops after maturity

A significant percentage (36.7%) of the farmers harvested their crops between 4 to 7 days after physiological maturity; followed by 21.7% who harvested 8 – 14 days after physiological maturity (Table 4.1).

Table 4.1: Percentage of farmers who harvested rice after physiological maturity

Harvest days after maturity	Frequency	Percentage (%)
1-3days	6	10.0
4-7days	22	36.7
8-14days	13	21.7
15-21 days	12	20.0
22-28 days	5	8.3
29-35 days	2	3.3
Total	60	100.0

4.1.3 Usage of different threshing methods for post-harvest processing

Most (58.3%) of the farmers indicated that they threshed their harvested produce by beating the panicles with sticks on the bare floor. 30.0% of the farmers stated that they threshed their panicles on tarpaulin using sticks. About 1.7% of the respondents indicated that they threshed using a machine on tarpaulin (Table 4.2).

Table 4.2: Percentage of farmers using different threshing methods for post-harvest processing

Threshing Method	Frequency	Percentage (%)
Beaten with sticks on floor	35	58.3
Beaten with sticks on tarpaulin	18	30.0

Machine threshes on bare floor	6	10.0
Machine threshes on tarpaulin	1	1.7
Total	60	100.0

4.1.4 Quantity of seeds stored for next planting season

A significant proportion of farmers (40%) stored about 20-50 kg of seeds for the next planting; 2.0% stated that they stored 650-1000 kg, and while 7.0% indicated that they stored 1100-2000 kg (Table 4.3).

Table 4.3: Percentage of farmers who stored designated quantity of seeds until the next planting season

Quantity of seeds stored	Frequency	Percentage (%)
20-50kg	24	40.0 25.0
50-100 kg	15	22.0
110-300 kg	13	5.0 2.0
350-600kg	3	7.0
650-1000kg	1	
1100-2000kg	4	
Total	60	100.0

4.1.5 Proportion of respondents utilizing each Materials and methods of storage

Most of the farmers (47%) indicated that their rice seeds were stored in nylon fertilizer bags stacked on wooden pallets followed by 27.0% who stored in jute sacks stacked on pallets (Table 4.4).

Table 4.4: Materials and methods of storage and percentage of respondents utilizing each method

Storage materials and methods	Frequency	Percentage (%)
Jute sacks on floor	1	2.0
Jute sacks on pallets	16	27.0
Nylon bags on pallets	28	47.0

Polyethylene bags	3	5.0
Straw cribs lined with thicker Poly bag	11	18.3
Lined Nylon fertilizer bag	1	2.0
Total	60	100.0

4.1.6 Number of days harvested panicles remained in the field before threshing.

Forty-three percent of farmers indicated that they left the harvested panicles in the field between 4-7 days before they threshed; followed by 25.0% who allowed 1-3 days in the field before threshing. Only (3%) of farmers left their panicles on the field for more than 29 days before threshing (Table 4.5).

Table 4.5: Number of days harvested panicles remained in the field before threshing and percentage of respondents

Days panicles left on field before threshing	Frequency	Percentage (%)
1-3 days	15	25.0
4-7 days	26	43.0
8-14 days	9	15.0
15-21 days	5	8.0
22-28 days	3	5.0
29-35 days	2	3.0
Total	60	100.0

4.2 SEED STORAGE STUDY

4.2.1 Temperature and humidity conditions in the storage room

There was continuous fluctuations of humidity and temperature in the storage room over the 12 week storage period. The maximum temperature of 28.9 ºC was recorded in weeks 8 and 9, whereas, the highest humidity of 73.1% was recorded in week 10 (Fig. 4.2). The average temperature was 27.87 ºC and Relative humidity was 67.6% over the entire storage period.

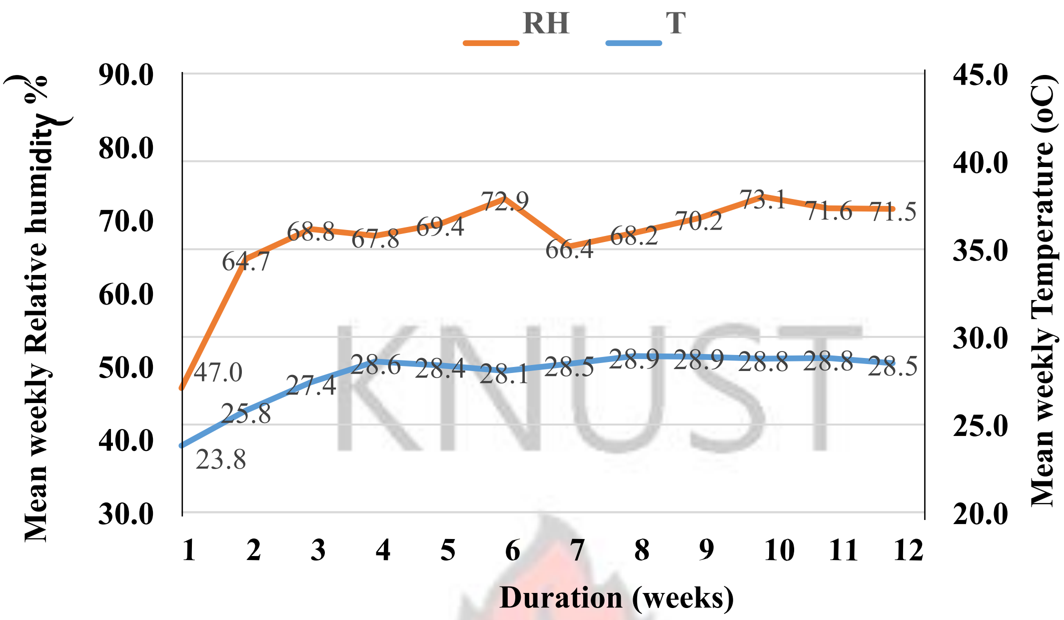

Figure 4.2: Weekly temperatures and humidity of the storage room

4.2.2. Moisture content of rice seeds before storage

There were significant differences ($p<0.05$) between the varieties of rice seeds. Jasmine-85 seeds recorded the highest moisture content (11.150), though similar to that of GR-18. Gomba seeds recorded the least moisture content (10.424), though not significantly different from Digang and GR-18. (Table 4.6).

Table 4.6: Moisture content of four rice varieties before storage

Varieties	Percent seed moisture content
Jasmine-85	11.2
Digang	10.4
GR-18	10.6
Gomba	10.4
Tukey's HSD (0.0):	0.63

4.2.3 Moisture content of rice seeds after storage

After a 90-day storage period, there was significant variety x storage material interaction for seed moisture content. Jasmine-85 seeds packaged in unlined nylon sacks recorded the highest moisture content (12.8 %) although similar to Digang, GR-18, and Gomba packaged in unlined nylon sacks and unlined jute sacks (Table 4.7). The least seed moisture content (11.1 %) after storage was recorded from GR18 packaged in lined nylon sack. Jasmine 85 seeds packaged in lined jute sack and lined nylon sack recorded similar low moisture content after storage. (Table 4.7). Among the packaged materials, seeds stored in unlined nylon sacks and unlined jute sacks recorded the highest moisture content (12.5%), significantly different from the lowest moisture content recorded from lined jute sack and lined nylon sack (11.8 %) (Table 4.7). Among the varieties, Jasmine-85 and Digang seeds recorded the highest moisture content significantly different from the lowest moisture content recorded from Gomba and GR-18 seeds (Table 4.7). Comparing the moisture content of the seeds before and after storage, there were increases in the moisture content of the seeds regardless of the storage material used. Jasmine-85 seeds had a 9 % increase; Digang recorded a 17.3 % increase; GR-18 recorded a 10.2 % increase and Gomba had a 13.5 % increase (Tables 4.6 and 4.7).

Table 4.7: Effects of storage materials on moisture content of four rice varieties stored for 90 days under ambient conditions

	Moisture Content (%)				
Storage materials	Jasmine-85	Digang	GR-18	Gomba	Mean
Unlined Nylon Sack	12.8	12.6	12.4	12.3	12.5
Unlined Jute Sack	12.7	12.6	12.3	12.3	12.5
Lined Jute Sack	11.8	12.1	11.3	11.4	11.6

Lined Nylon Sack	11.6	11.6	11.1	11.2	11.4
Mean	12.2	12.2	11.8	11.8	

Tukey's HSD (0.0): SM = 0.3 ; VAR = 0.3 ; SM x VAR = 1.07

4.2.4 Germination percentage before storage

Significant differences (p<0.01) were observed between varieties for germination percentage before storage. The highest germination value was recorded from seeds of GR-18 (79.500%), though not significantly different from those obtained for seeds of Jasmine-85 and Digang; while the lowest germination percentage was recorded on Gomba (54.187%) (Table 4.8)

Table 4.8: Germination percentage of four rice varieties before storage

Varieties	Germination percentage
Jasmine-85	74.63
Digang	73.94
GR-18	79.50
Gomba	54.19
Tukey's HSD (0.0):	12.948

4.2.5 Percent germination after storage

There were no significant interactions as well as the main effects of the treatments for percent germination after storage. Germination percentage ranged from 62.6 % to 63.9 %. In comparison to percentage germination before storage of the varieties (mean of 70.6 %) (Table 4.8), there was a decline in percentage germination after storage (mean of 63.3 %).

4.2.6 Seed germination speed before storage

The speed of germination before seed storage was not affected by variety (Table 4.8). The range of germination speed was 28.13 Seedling day^{-1} to 35.69 Seedling day^{-1}.

4.2.7 Seed germination speed after storage

There were significant differences between the storage materials for the speed of germination of the seeds. Seeds stored in woven unlined nylon sacks recorded the highest germination speed (51.4 seedlings day^{-1}). The lowest germination speed was recorded by seeds stored in lined nylon sacks (44.9 seedlings day^{-1}), (Table 4.9).

Table 4.9: Effects of storage materials on seed germination speed of four rice varieties after storage

Storage material	Seed germination speed (seedlings day^{-1})
Unlined Nylon Sack	51.4
Lined Jute Sack	48.2
Unlined Jute Sack	47.3
Lined Nylon Sack	44.9
Tukey's HSD (0.0):	.3

4.2.8 Seed electrical conductivity before storage

There were significant differences between the varieties for seed electrical conductivity. Digang seeds recorded the highest conductivity value (23.76 µS cm^{-1}g^{1}), though not statistically different from conductivity values obtained for seeds of Jasmine-85 and GR-18; while Gomba seeds recorded the least (16.8 µS cm^{-1}g^{-1}) (Table 4.10).

Table 4.10: Seed electrical conductivity of four rice varieties before storage

Varieties	Seed electrical onductivity (μS $cm^{-1}g^{-1}$)
Jasmine-85	20.73
Digang	23.76
GR-18	20.36
Gomba	16.84
Tukey's HSD (0.0):	4.771

4.2.9 Seed electrical conductivity after storage

There were significant differences between the storage materials for seed electrical conductivity after storage. Seeds stored in woven unlined nylon sack had the highest conductivity (21.81 μS $cm^{-1}g^{-1}$) while the lowest conductivity was recorded by seeds stored in lined nylon sack (16.8 μS $cm^{-1}g^{-1}$) (Table 4.11).

Table 4.11: Effects of storage materials on seed electrical conductivity of four rice varieties after storage

Storage Material	Seed Electrical conductivity (μS $cm^{-1}g^{-1}$)
Unlined Nylon Sack	21.82
Lined Jute Sack	20.78
Unlined Jute Sack	20.69
Lined Nylon Sack	18.39
Tukeys HSD (0.05):	4.771

4.2.10 Physical Purity before storage

There were significant difference between varieties for physical purity. Seeds of Gomba and GR-18 had the highest physical purity of 99.7 %, though not significantly different from that of Digang. Seeds of Jasmine-85 recorded the least physical purity of 99.1%), though similar to Digang (Table 4.12).

Table 4.12: Physical Purity of four rice varieties before storage

Varieties	Physical Purity of Seeds (%)
Jasmine-85	99.1
Digang	99.5
GR-18	99.7
Gomba	99.7
Tukey's HSD (0.0):	0. 2

4.3 Seed storage insects identification and population

Tribolium casteneum, and *Prostephanus truncatus* were the insects identified in the rice varieties during storage. There were no significant interactions among the storage materials and varieties for the storage insects identified. However, for each insect identified there were significant differences in their population among the rice varieties (Table 4.13).

For *Tribolium casteneum,* GR 18 seeds recorded the highest number (11.5), significantly greater than Digang, which had the least (1.5) number of *Tribolium casteneum* (Table 4.13). Similarly for *Prostephanus truncates,* GR 18 seeds recorded the highest number (17.95), significantly greater than Digang, which had the least number (1.44) (Table 4.13).

Table 4.13: Mean number of seed storage insects identification and population in the rice varieties

Variety	Mean number of storage insects	
	Tribolium casteneum	*Prostephanus truncatus*
Jasmine-85	2.81	2.94
Digang	1.50	1.44
GR-18	11.50	17.94
Gomba	2.19	2.38
Tukey's HSD (0.05)	1.293	1.650

CHAPTER FIVE

5.0 DISCUSSION

5.1 Gender characteristics of rice farmers

The fewer females (28 %) compared to males (72 %) in rice cultivation in Northern Ghana is a characteristic of the area since women are traditionally involved in mostly threshing and winnowing (SARI/IFPRI, 2013). In Southern Ghana, 70% women are involved in rice production in the Volta and Ashanti regions (Donya, 2000). However, in recent times women across Ghana are also involved in operations such as selection of seeds, broadcasting, weeding, harvesting, threshing and winnowing (SARI/IFPRI, 2013).

5.2 Harvesting and postharvest practices

Majority of the farmers harvested their rice seed within two weeks after maturity. Most farmers harvest their seed between the months of October to December (Hammatan period) during which time the humidity was low and the temperatures high. This period allowed the rice seeds to dry completely on the farm. This is in agreement with Tekrony, (2003) who indicated that to harvest seed directly, the seed must dry down on the plant before it reaches harvest maturity. Guisse (2010) also stated that the time of harvesting seed can affect the viability and storage duration of the seeds and as such the best phase to harvest a rice crop is when moisture content of the grain is between 20-25% or when 80-85% of the grains are straw colored. A significant number (43%) of farmers in the study area left their harvested rice for about a week before threshing (Table 4.5). This practice is not appropriate since the longer the harvested panicles remained in a stack, the higher the chances of increased deterioration or seed vigour reduction (Guisse, 2010). Threshing of harvested rice seeds was manually done by most of the farmers using sticks to beat the panicles arranged on bare floor. This agrees with CORAF/WECARD (2011) that in areas where the farm sizes and outputs are small, threshing is done manually because the use of combine harvesters is difficult. Majority of the farmers stored just about one bag (50kg) of seed which was a reflection of their farm sizes and varieties used. Majority of farmers stored their rice seeds in nylon fertilizer bags on raised racks in their rooms, a practice reported to be common for household storage of grains and seeds (Sethi and Malaviya 2000). Majority of the farmers stored their saved seed for about 6 months depending on the onset of the rains and the farmer's finances.

5.3 Effects of storage materials on seed quality attributes of rice varieties

Seeds stored in woven unlined nylon sacks and unlined jute sacks increased in moisture content after storage (Table 4.7). This could be due to the porous and pervious nature of the packaging material which allowed the seeds to absorb moisture from the environment. This agrees with Rai *et al*. (2011) who stated that in order to reduce moisture increase in seeds from the storage environment due to their hygroscopic nature, it is better to store the seeds in moisture proof containers like polythene bag, aluminum foil, tin or any sealed container to maintain the quality for longer period. Seeds that were stored in lined nylon sack had the lowest moisture content. This is because both lining and nylon materials were impervious and therefore offered double protection to the seeds in terms of moisture absorption from the environment.

Germination percentage generally decreased from a mean of 74% before storage to a mean of 64% after the storage period. This could be due to the nature of the storage material which either allowed moisture to be absorbed by the seeds or created conditions for seed deterioration and subsequent reduction in germination. Seeds stored in unlined nylon sack were higher in germination speed. The woven nature of the unlined nylon sack made it less impervious compared to the jute sack material, and therefore did not provide conditions for seed deterioration and subsequent germination loss. Similar findings were reported by Rai *et al*., (2011) who stated that seeds stored in impervious sealed containers stored better compared to moisture pervious containers and had positive effects on germination. Also heat accumulated in the lined bags could have caused molds to develop causing an increase in free fatty acids (FFAs), and rancidification Jonfia-Essien *et al*., (2010) which causes seed ageing and deterioration while in storage (Iqbal, 2002). Similar studies confirmed by (Booth and Bai, 1999) reported that free fatty acids can damage the lipid bilayer especially of mitochondria leading to reduced energy production which affects the germination speed of seeds.

Although Digang recorded the highest conductivity of 23.76µS $cm^{-1}g^{-1}$, and Gomba the least conductivity of 16.8 µS $cm^{-1}g^{-1}$, both could be characterized as seeds with high vigour (Milosevic *et al.,* 2010), and therefore were suitable for early sowing in unfavourable conditions. Moreover, the vigour of the seeds still within the high vigour range regardless of the storage material used. Consequently to maintain the vigour of rice seeds during storage, any of the storage materials used in the present study could be qualify for use.

5.4 Effects of storage materials and rice varieties on population of storage insects

The red flour beetle (*Tribolium casteneum)* was found after three months of storage in all four rice varieties used in the experiment. This indicated the importance of this storage pest on the viability of rice seed during storage. The results of the present study contradicts the findings of Dharmasena and Abeysiriwardena (1995) who reported on the susceptibility of three rice varieties to red flour beetle in their experiment after seventh months of storage. The rice varieties used in the present study were more susceptible to *Tribolium casteneum* within 3 months of storage period of which GR 18 seeds was found to be more susceptible to the storage insect.

This observation could be due to the varietal differences and agrees with Dharmasena and Abeysiriwardena (1995) who found out that, among the three varieties used; A 405 rice variety was highly susceptible to *Tribolium casteneum* compared to the other two.

The variety GR18 also recorded a higher population of *Prostephanus truncatus* indicating that this variety is also more attractive to the larger grain borer than the other three varieties. This could be due to its softer seed coat.This agrees with Mulungu *et al*., (2012) who indicated that high infestation of rice weevils was due to the soft texture of the seed coat.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The findings from the field survey indicated that majority of farmers stored their rice seeds in storage bags, such as woven jute and nylon bags which were either placed on wooden planks or on the bare floor. Most farmers stored in woven nylon bags than the woven jute bags.

Unlined nylon sack stored seeds best compared to the other three packaging materials hence reduced the rate of deterioration of the seeds. All four storage materials resulted in high vigour of the rice seeds.

Jasmine-85 and Digang showed higher seed vigor than the rest of the varieties before storage, however all the four rice varieties had seeds with very high seed vigor after storage since the electrical conductivities were within the range for high seed vigour. Digang seeds had the highest germination percentage.

GR18 variety recorded the highest infestations of *Tribolium casteneum and Prostephanus truncates* and Digang recorded the least infestations of both storage insects.

The study revealed that Digang seeds stored in the woven unlined nylon sack gave the highest germination speed and low conductivity values with the least insect infestations (*Tribolium casteneum* and *Prostephanus truncates*) after the three months storage.

6.2 Recommendations

1. Rice varieties should be stored for periods longer than three months to determine the effects of the longer term storage and packaging materials on the seed vigor.
2. Seeds should be aged artificially to determine which variety has the potential to store for a longer period.

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APPENDICES

APPENDIX I

Analyses of variance table for Physical Purity before storage

Source	DF	SS	MS	F	P
Rep	3	0.3762	0.12542		
PM	3	0.6713	0.22375	1.12	0.3509
VAR	3	3.4287	1.14292	5.72	0.0021
PM*VAR	9	3.0325	0.33694	1.69	0.1204
Error	45	8.9887	0.19975		
Total	63	16.4975			

Grand Mean 99.506

CV 0.45

APPENDIX II

Analyses of variance table for moisture content after storage

Source	DF	SS	MS	F	P
Rep	3	0.8255	0.27516		
PM	3	17.3380	5.77932	32.93	0.0000
VAR	3	3.2905	1.09682	6.25	0.0012
PM*VAR	9	0.4989	0.05543	0.32	0.9656
Error	45	7.8970	0.17549		
Total	63	29.8498			

Grand Mean 11.998

CV 3.49

APPENDIX III

Analyses of variance table for moisture content before storage

Source	DF	SS	MS	F	P
Rep	3	6.1188	2.03959		
PM	3	0.9815	0.32717	0.74	0.5319
VAR	3	5.5463	1.84876	4.20	0.0106
PM*VAR	9	2.2851	0.25390	0.58	0.8089
Error	45	19.8095	0.44021		
Total	63	34.7411			

Grand Mean 10.659

CV 6.22

APPENDIX IV

Analyses of variance table for Germination percent after storage

Source	DF	SS	MS	F	P
Rep	3	942.55	314.182		
PM	3	183.17	61.057	3.04	0.0384
VAR	3	16.67	5.557	0.28	0.8418
PM*VAR	9	215.64	23.960	1.19	0.3224
Error	45	903.20	20.071		

Total	63	2261.23			

Grand Mean 63.391

CV 7.07

APPENDIX V

Analyses of variance table for Germination percent before storage

Source	DF	SS	MS	F	P
Rep	3	1275.9	425.29		
PM	3	121.1	40.38	0.21	0.8860
VAR	3	6014.6	2004.87	10.64	0.0000
PM*VAR	9	1803.5	200.39	1.06	0.4074
Error	45	8478.6	188.41		
Total	63	17693.8			

Grand Mean 70.563

CV 19.45

APPENDIX VI

Analyses of variance table for Seed Germination speed index after storage

Source	DF	SS	MS	F	P
Rep	3	1040.38	346.792		
PM	3	346.38	115.458	3.53	0.0222
VAR	3	39.63	13.208	0.40	0.7512
PM*VAR	9	320.25	35.583	1.09	0.3910
Error	45	1473.13	32.736		
Total	63	3219.75			

Grand Mean 47.938

CV 11.94

APPENDIX VII

Analyses of variance table for Seed Germination speed index before storage

Source	DF	SS	MS	F	P
Rep	3	10145.3	3381.77		
PM	3	387.7	129.22	0.57	0.6353
VAR	3	433.4	144.47	0.64	0.5924
PM*VAR	9	1364.6	151.63	0.67	0.7286
Error	45	10136.5	225.25		
Total	63	22467.5			

Grand Mean 32.766

CV 45.81

APPENDIX VIII

Analyses of variance table for Electrical conductivity after storage

Source	DF	SS	MS	F	P
Rep	3	25.66	8.553		
PM	3	100.28	33.427	1.31	0.2839
VAR	3	384.94	128.314	5.02	0.0044
PM*VAR	9	193.03	21.448	0.84	0.5851
Error	45	1151.15	25.581		
Total	63	1855.07			

Grand Mean 20.422

CV 24.77

APPENDIX IX

Analyses of variance table for Electrical conductivity before storage

Source	DF	SS	MS	F	P
Rep	3	1409.39	469.796		
PM	3	37.91	12.638	0.47	0.7067
VAR	3	841.07	280.356	10.36	0.0000

PM*VAR	9	366.15	40.683	1.50	0.1760
Error	45	1217.73	27.061		
Total	63	3872.24			

Grand Mean 22.016

CV 23.63

APPENDIX X

Analysis of Variance Table for Larger Grain Borer (Transformed)

Source	DF	SS	MS	F	P
PM	3	0.161	0.0536	0.03	0.9941
VAR	3	54.479	18.1595	9.01	0.0001
PM*VAR	9	18.951	2.1056	1.04	0.4201
Error	48	96.790	2.0165		
Total	63	170.380			

Grand Mean 2.1241

CV 66.85

APPENDIX XI

Analysis of Variance Table for *Sitophilus oryzae*

Source	DF	SS	MS	F	P
PM	3	0.23605	0.07868	2.71	0.0555
VAR	3	0.17711	0.05904	2.03	0.1219
PM*VAR	9	0.60719	0.06747	2.32	0.0293
Error	48	1.39445	0.02905		
Total	63	2.41480			

Grand Mean 1.0500

CV 16.23

APPENDIX XII

Analysis of Variance Table for *Tribolium casteneum*

Source	DF	SS	MS	F	P
PM	3	2.0238	0.67459	0.54	0.6541
VAR	3	25.6693	8.55644	6.91	0.0006
PM*VAR	9	9.3816	1.04240	0.84	0.5821
Error	48	59.4539	1.23862		
Total	63	96.5286			

Grand Mean 1.9975

CV 55.72