KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES FACULTY OF AGRICULTURE, DEPARTMENT OF HORTICULTURE

EFFECTS OF THRESHING METHODS ON SEED QUALITY OF THREE RICE VARIETIES STORED FOR A PERIOD OF FOUR MONTHS

A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (SEED SCIENCE AND TECHNOLOGY) DEGREE

BY

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DECLARATION

I, Christopher WOODIE, hereby declare that this thesis submitted in partial fulfilment of M.Phil degree is the result of my personal work, which has not been presented elsewhere for any degree. References to other works have been duly acknowledged.

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DEDICATION

I dedicated this piece of work to my parents Mr. Joe Thomas Woodie and Mrs. Suba Woodie and my late uncle Mr. P J Magbity (of blessed memory).

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ABSTRACT

The field and laboratory work were done between June 2014 and April 2015 to evaluate the effects of different threshing methods and storage on the seed quality of three rice varieties. The field work was done in Nobewan at the Anum valley in the Ashanti region of Ghana. The area lies between latitude 6^{o} 35’ to 6^{o} 54’ north and longitude 1^{o} 4’ to 1^{o} 23’ west of the Greenwich meridian. The field was laid out using 3 x 3 Factorial in the Randomized Complete Block Design (RCBD) with three replications.

The laboratory experiment was done at the seed quality control unit laboratory, Grains and Legumes Development Board Kumasi, Ghana. The experiment was conducted as factorial on the basis of completely randomized design in three replications. The treatments were variety at 3 levels (Nerica-L41, Jasmine-85 and Sikamo) and the threshing method at 3 levels (Box or bambam, Drum and Machine) and the measured seed quality parameters namely analytical purity, standard germination test and vigour tests including 1000 seed weight, seedling vigour index and conductivity test were analyzed before and after a storage period of four months. The result revealed that machine threshing recorded the highest percentage of broken grains whilst box threshing had the lowest. Moreover, Jasmine-85 threshed using machine recorded the highest germination while Sikamo threshed using machine recorded the lowest seed germination after storage. Electrical conductivity values increased after storage although the values were still within the high seed vigour bracket. However, 1000 seed weight increased after storage due to moisture absorption by the seeds during storage.

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ABBREVIATIONS, ACRONYMS AND SYMBOLS

%	percentage
<	less than
µS/cm/g	Micro siemens per centimeter per gramme
1^{st}	first
AGRA	Alliance for Green Revolution in Africa
ANOVA	analysis of variance
AOSA	Association of Seed Analyst
AV	average
CRBD	Completely Randomized Block Design
CSIR	Council of Scientific and Industrial Research
CV	coefficient of variation
FAO	food and Agricultural Organisation
ha	hectre
IRRI	Irrigation Rice Research Institute
ISTA	International Seed Testing Association
JICA	Japanese International Cooperation Agency
Kg	kilogramme
L	lowland variety
LSD	least significant difference
MOFA	Ministry of Food and Agriculture
MS^{-1}	Minutes per seconds
NPK	Nitrogen Phosphorus Potassium
ºC	degree Celsius
RCBD	Randomized Complete Block Design

RH	Relative humidity
SLARI	Sierra Leone Agricultural Research Institute
SSA	Sub Sahara Africa
STSQCA	Seed Testing and Seed Quality Control in Asia
Temp	Temperature
TM	Threshing Method
US$	United State Dollar
USDA	United State Department of Agriculture
V	variety
WARDA	West Africa Rice Development Association

CHAPTER ONE

1.0 INTRODUCTION

Rice (Oryza sativa. L.) is one of the world's main staple crops, with nearly 2.5 billion people depending on it as their main food (FAO, 2004). Rice is cultivated in at least 144, mostly developing countries and is the primary source of income and employment for more than 100 million households in Africa and Asia (FAO, 2004). In Africa, rice is the fastest growing food source (Nwanze et al., 2006). It provides more than one third of cereal calorie intake in West Africa and up to 85% in traditional rice producing countries like Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia and Côte d'Ivoire. According to FAO (2008), rice represents 27% of energy and 20% of alimentary protein. The germ and the husk discarded during threshing are rich source of vitamins – especially vitamin B1 – minerals, fibre and enzymes.

In Ghana, rice is the second important cereal after maize and is fast becoming a cash crop for many farmers (Ragasa *et al*., 2013). Annual per capita consumption of rice is growing rapidly from 17.5 kilogram in 1999-2001 to 24 kilogram in 2010-2011 (MOFA 2011a), and its demand is projected to be at a rate of 11.8 percent in the medium term (Ragasa *et al*., 2013). Nonetheless, the totality of rice grain obtained from the local rice fields only meet about 40% of the country's rice demand, making Ghana a net importer of the commodity (FAO, 2008). In 2009, the country imported over 350,000 tons of milled rice worth 600 million US dollars (Duffuor, 2009).

In Ghana, low rice yields have been attributed to poor seed quality, among others (Al-Hassan *et al.,* 2008; JICA, 2008; MOFA, 1999, 2000). Contributory factors to such low seed quality are inappropriate threshing methods and storage. During threshing, internal cracks or fissures may occur along the embryo of the seeds. These fissures may retard the germination potential, viability and vigor of the seeds leading to poor seedling establishment. They may also serve as entry points for pathogen to destroy the seeds in storage. However, it is reported that good quality seed could increase yield by 5-20% (Rickman *et al*., 2006). The main objective of the study therefore was to evaluate the effects of different threshing methods and storage on the seed quality of three rice varieties.

Specifically the objectives were to;

1. determine the effects of threshing methods on the germination potential of three rice cultivars before and after storage.
2. evaluate the effects of threshing methods on seed vigour before and after storage of three rice cultivars.
3. determine the extent of mechanical damage resulting from the threshing methods.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 TAXONOMY AND GEOGRAPHICAL LOCATION OF RICE

Rice is an annual grass which belongs to the genus *Oryza* and the family poaceae (Agropedia, 2009). This cereal is a monocot crop that can self-pollinate (Smith, 1998). In the taxonomy database, there are 24 species under the genus *Oryza* (thus genomes A to K) and a chromosome number of 2n = 24 (IRRI, 2005b). Among its species only two are cultivated; these are *Oryza sativa* which originates from Asia and *Oryza glaberrima* which originates from Africa (Vaughan *et al*., 2003).

Oryza sativa is the most commonly grown species throughout the world. It is native to Southeast Asia, but has spread throughout tropical and subtropical environments (Vaughan *et al.*, 2003). *Oryza sativa* is differentiated into two sub-species based on geographical conditions: the *indica* type and the *japonica* type (Linares, 2002). *Oryza glaberrima* is limited to Western Africa. This species is less yielding compared to *Oryza sativa* but resistant to several stresses (WARDA, 1996; Jones *et al*., 1997; Sarla *et al*, 2005; Futakuchi *et al.*, 2009). Although they are distinctively different from each other, *Oryza glaberrima and Oryza sativa* are used as the background parents in varieties amelioration programmes.

2.2 AFRICA'S RICE ORIGIN

Currently, rice is grown in over 75% of the African countries, with a total population close to 800 million people. Rice is the main staple food of the populations in Cape Verde, Comoros, Gambia, Guinea, Guinea-Bissau, Liberia, Madagascar, Egypt, Senegal and Sierra Leone. It is also an important food of the populations in Côte d'Ivoire, Mali, Mauritania, Niger, Nigeria, and Tanzania. In addition, rice has become an important food security factor in Angola, Benin, Burkina Faso, Chad, Ghana and Uganda.

Although majority of rice varieties cultivated on the continent today belong to *O.* Sativa, with China as its origin, over 10,000 years ago. The African continent is the home of Oryza. glaberrima where it has been domesticated for about 3,500 years. This variety has mainly been confined to West Africa where it had been the most commonly grown rice. The white Asian type, O. sativa, was introduced on the continent towards the end of the first millennium via Madagascar (WARDA, 2004). Its rapid spread in most African countries has however been due to the rigorous efforts of the international Rice breeding centers, namely International Rice Research Institute (IRRI) in the Philippines and later from the West African Rice Development Authority (WARDA) in Ivory Coast.

2.3 IMPORTANCE OF RICE

Majority of the people in the world eat rice. It is the second most important cereal in the world today and provides, together with wheat, a large proportion (95%) of the total nourishment of the world's population. It is the daily food for over 1.5 billion people (Boumas, 1985, Juliano, 1993). The reason for it being so popular is that it is easily digested. Juliano (1993) found that rice is an essential food in the diet of one third of the world's population and further stated rice production and consumption is concentrated in Asia where more than 90% of the world's rice is grown and consumed. The 155 million hectares cultivated globally produce about 596.5 million metric tons of paddy rice per year (Li, 2003). Rice cultivated under a wide range of climates, soils and production systems, is subjected to many biotic and abiotic stresses that vary according to site. Consumption per capita and consumer preferences for a given rice type also vary from region to region (Juliano, 1993).

Rice is now a major staple food for millions of people in West Africa (Basorun, 2003). The author observed that presently, the annual demand for rice in the Sub-Region is estimated at over 8 million metric tonnes. Rapid population growth (estimated at 2.6% per annum), increasing urbanization and the relative ease of preservation and cooking have influenced the growing trend in rice consumption. Since the 1970s, production of rice has been expanding at the rate of 5.1% per annum, with 70% of the growth due to increased area cultivated to rice, and only 30% due to higher yields, per unit area (Anon, 2008a).

Presently, an estimated 4.4 million hectares are under rice cultivation in West Africa (Somado *et al*., 2008). Total rice paddy production in the sub-region is estimated to be about 6.2 million metric tonnes (Anon., 2008b).

Unfortunately, West Africa does not produce the quantity of rice needed to meet its demand. To fill that gap, rice has to be imported. The Food and Agriculture Organization of the United Nations (FAO) estimated in 2006 that current rice imports into the sub-region have grown to more than 6 million metric tonnes per year costing over $1.5billion in scarce foreign exchange each year (Somado *et al*., 2008). This has worrying consequences for the balance of payments of these countries. Imports of this magnitude signify a major setback for broader development and poverty reduction efforts (Somado *et al.*, 2008).

Berisavljevic *et al.* (2003) reported that rice is important to Ghana's economy and agriculture, accounting for nearly 15% of the Gross Domestic Product. This sector of agriculture provides employment for a lot of rural inhabitants. Due to the shift in the diet of Ghanaians to rice consumption, particularly those in the urban areas, imports of rice have been increasing steadily since the 1980s. Imported rice is estimated to account for more than 50% of all rice consumed in the country (Berisavljevic *et al.*, 2003).

The increase in demand for imported rice is primarily attributed to increased income, good storability and ease of cooking (Shabbir *et al*., 2008). Rice consumption increased by over 20% per year in the 1990s, with the increased demand being met by imports from the Far East and the Americas (Berisavljevic *et al.*, (2003). They indicated that imported rice, which is also perceived to be of better quality than local rice, is generally sold at higher prices. Currently, local production of rice hardly meets the annual demand of Ghana (Takoradi, 2008).

2.4 BACKGROUND TO NERICA

Nerica, a non- aromatic variety was developed in the early 1990s, by a team of rice breeders led by Dr Monty Patrick Jones at the M' be' research center of WARDA in Bouake, Ivory Coast. Nerica is a stable and fertile progeny developed from crosses between Asian rice, O. sativa and African rice O. glaberrima Steud (Jones *et al.*, 1997). Hundreds of upland interspecific progeny have been generated thereby opening new gene pools and increasing biodiversity of rice for the world of science and end-user farmers. This variety comprises upland Nericas and lowland irrigated Nericas. Nerica varieties have been evaluated and characterized for a range of agronomic traits and reactions to key African endemic diseases and pests. Generally, Nerica varieties have early maturation duration, resistance to local stresses, high yielding advantage, high protein content and good taste. Today, NERICA is a symbol of hope for food security in SSA - the most impoverished region in the world, where a staggering one-third of the people are undernourished, and half the population struggle to survive on US$1 a day or less.

2.5 JASMINE-85 BACKGROUND

Jasmine-85 is an aromatic rice variety developed in Thailand in 1966 by Doctor Ben Jackson a rice breeder at the International Rice Research Institute. In 1989, the USDA in collaboration with IRRI, University of Arkansas, Louisiana State University, and Texas A&M University, released Jasmine 85 to American farmers. This variety grows rapidly, gives high yield, and carries good resistance to pests in southern United States. It also suppresses the growth of weeds in the surrounding area. All these desirable features allow US farmers to grow Jasmine-85 as Organic Rice, for which health-conscious US consumers are willing to pay a premium price (Tanasugarn, 1998). One main problem with Jasmine-85 is the many broken grains found after milling, which tend to drive the price down (Hagrove, 1997).

2.6 BACKGROUND TO SIKAMO

Sikamo (Tox 3108 or GR 22) was developed in Ghana to replace non- performing rice varieties in inland valleys and irrigated ecologies across the country. This high yielding, disease resistant and less tolerant to drought variety was officially released, although many farmers were already planting it before it was released and estimates suggest that it was planted in 20 percent of irrigated area and 15 percent of lowland rain fed areas in 1997 (Dalton and Guei, 2003). Sikamo has high nitrogen use efficiency, has good taste, is blast and drought tolerant, and is high yielding (that is, higher than the currently popular variety called Jasmine-85); however, it is difficult to thresh and has no aroma, which makes it less attractive to traders, and therefore farmers changed their Sikamo to Jasmine-85 and other aromatic varieties (Ragasa *et al.*, 2013).

2.7 BASIC POST HARVEST PRACTICES OF RICE

Postharvest management of rice includes harvesting, threshing, drying, storage and milling the rice crop. Harvesting and threshing methods of rice vary widely from farmer to farmer and also from country to country. The levels of mechanization, from country to country also differ widely. The methods may either be manual, animal or mechanical operated (FAO, 2007).

2.7.1 Harvesting

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 straw colored and the grains in the lower parts of the panicle are in the hard dough stage. This is about 30 days after flowering. If the crop is harvested too late, many grains are lost through shattering or drying out and are cracked during threshing. If rice is harvested too early, there will also be many immature seed grains and this will reduce quality. Harvesting methods, threshing operation and type of cylinder play a major role on the amount of rice losses and quality (Alizadeh and Bagheri, 2009). Immature rice kernels are very slender and chalky and this results in excessive amounts of bran and broken grains during milling.

The two harvesting methods that are mostly used in Ghana are Panicle and Sickle harvesting. 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 labor cost.

2.7.2 Threshing

Threshing operation is considered as one of the foremost important and effective postharvest operation on quality and quantity of paddy Alizade and Bagheri (2009).

Threshing is the postharvest operation of separating or removal of the paddy grains from the rice straw by striking and/or rubbing. The impact and rubbing action strips the grain from the stem. Threshing is a major aspect that is usually carried out after harvesting of grain crops.

This is a very important operation in rice postharvest handling, which if not handled properly results in broken or damage seeds or grains and mixing with other foreign matter including sand, stones and other rice varieties which present more challenges for processing (Staple Crop Programme,2011). Alizadeh and Bagheri (2009) studied the effect of different rice threshing methods on quantitative and qualitative losses. Their results showed that the threshing method had significant effect on grain losses namely broken and cracked rough rice as well as broken rice percentage after milling.

Miah *et al*. (1994) in their research showed that percentage of grain damage and unthreshed grains are significantly affected by the threshing method. Their results also showed that germination rate and storage life depend on the method of threshing. (Sosnowski and Kuzniar, 1999, Khazaei *et al*., 2009) mentioned that soybean seeds especially during threshing undergo severe pressures on metal elements of harvest machines which results in broken seeds, seed coat cracks and also invisible internal damage. The extent and type of damage depend not only on the threshing machine designing properties and effectiveness but also on the threshing conditions and cultivar properties (Sosnowski and Kuzniar, 1999, Khazaei *et al.*, 2009).The extent of damage in seeds is a complex interaction that involves some parameters that affect final quality of seed such as seed moisture content, impact velocity, cultivar of seed, seed size and loading times (Khazaei *et al*., 2007).

Moreover, Feiffer *et al*. (2001) reported that the crop cultivar, moisture, and biometrical indices also influenced the threshing process.

2.7.3 Threshing Methods

In the rice farming zones, threshing is often carried out manually with sticks and rammers which has an (output capacity ≤1ton per day), or is mechanized, carried out with pedal threshers whose output capacity is around 100 to 150 kg/hr (Akintayo *et al.*, 2008).

Manual threshing: Traditional rice farmers carry out threshing in different ways. This involves the beating of the grains from the stalk (Nkama 1992). These methods are however local, inefficient, time consuming, low output and laborious. Contamination of paddy with sand, stone, immature grain and other foreign materials is high. In addition, they are only suitable for small scale farming, they include;

Bambam- This method involves beating sickle harvested rice against a wooden box with an opening to collect the detached grains.

Drum or Barrel – Sickle harvested rice is beaten against a drum or barrel on a floor covered with tarpaulin. The detached grains are collected for winnowing.

Foot threshing or trampling: this involves the use of bare feet or animals to thresh the crop. To perform this operation successfully, the crop is spread over a mat or canvass and workers trample with their own feet or use their animals. In many countries in Asia and Africa, and in Madagascar, the crop is threshed by being trodden underfoot (by humans or animals); this method often results in some losses due to the grain being broken or buried in the earth (Food Agency Organization 1995). After threshing, the straw is separated from the grains and cleaning of the grain is done by winnowing.

Flail: the use of a flail or stick for thrashing the crop.

Intermediate Technology: There is however an intermediate technology for rice threshing. This involves the use of semi motorized and completely motorized rice threshers. These are already available in several places in sub Saharan Africa, particularly in irrigated areas or developed low lands. A number of small, medium, and large threshers have been in existence for quite a long time, but due to low or poor performance in comparison with the traditional methods, they have not been adopted to a significant extent. Some are hand-held threshers and pedal operated ones (Chabrol, *et al.,* 1996).

For the pedal operated threshers, the pedals are attached to an overhead drum that is perforated to create fingers. As the machine is pedaled and the straw placed on the drum the resulting centripetal forces loosens the grain from the straw. Because small straws, chaff, and foreign matter drop along with the threshed grain, the grains must be separated using a sieve or by winnowing. The output is about 500kg per day. This is an improvement over the manual threshing. However the pedal thresher is very laborious, has limited output and is suited for only small farms. There is already an improvement on the pedal thresher. This pedal is replaced with a motor, such that the operator stands and places the straw over the exposed spike- like drum. It gives higher output and is less drudgery but still suited for small farms.

Threshing using hand tractor: The crop is spread on compacted soil in the field. The operator steers his tractor in circles over the crop until all grains are removed from the panicles. One problem is the contamination of grains with spores of fungi from the soil.

Mechanized Threshing Machines: Over the decades, rice growing communities have attempted to produce motorized threshers. Where success is recorded, such threshers become popular among such rice growing communities. The need to develop motorized threshers is born-out of the laborious nature of threshing process. Among such threshers are; India rice threshers which include Olphad and general purpose threshers (Michael and Orjha, 1987), Japanese type rotary paddy rice threshers, IRRI axial flow thresher, etc.

Two main types of stationary threshing machines have been developed. The machine of Western design is known as "through-flow" thresher, because stalks and ears pass through the machine. It consists of a threshing device with pegs, teeth or loops, and (in more complex models) a cleaning-winnowing mechanism based upon shakers, sieves and centrifugal fan. In the 70s, IRRI developed an axial *flow thresher*, which has been widely manufactured at local level (Saxena, *et al.*, 1971). More recently, a small *mobile thresher* provided with either one or two threshers was developed. This machine has been widely adopted in many rice-growing areas (Policarpio and Mannamy 1978). The simple design and work rates of these machines seem to meet the requirements of rural communities (Food Agency Organization 1995).

Hold-on thresher: Hold- on threshers consist an open rotating drum with teeth which will comb and strip the paddy from the straw shoots. The drum may use peg teeth or wire hoops to comb. The operator grips the base of the harvested straw and holds it against the threshing drum.

Feed-in thresher: The crop is fed into a feed-in thresher, and the straw circulates between a rasped drum and the casing, causing the paddy to fall through a grate into a collection chute. Feed-in threshers may be tangential flow, or axial flow. This design is typically used in industrial threshing machines.

Ponican *et al*. (2009) investigated threshing mechanism parameters of maize crop. They concluded that peripheral speed and clearance between cylinder and concaves were the most important factors affecting the crop quality. Their experiment results with the tangential threshing mechanism showed that with increasing the cylinder peripheral speed from 9.4 to 21.4 m s^{-1}, the grain damage increased from 3.8 to 6.01%.

Ajav and Adejumo (2005) evaluated an okra thresher with variable parameters such as concave clearance, seed moisture content, and cylinder speed. The results proved that germination of threshed seeds was significantly influenced by moisture content, cylinder speed, and concave clearance.

2.8 DRYING

The main reason why rice seed should be dried is to reduce its moisture and active respiration so that its nutrients will not be quickly exhausted, to cause deterioration. Moisture promotes the growth of harmful insects and microorganisms, which also cause rice to deteriorate. The germination rate of rice is lowered and toxins are produced by the growth of mould. Consequently, it is indispensable to reduce moisture in rice to prevent deterioration (Wimberly, 1983). Rice grains should be dried to less than 14% moisture content immediately after threshing. When seeds are to be stored for a longer duration, they should be dried at moisture content between 11% -13% and preferably stored in a sealed container. During drying, the seeds should be thoroughly and evenly raked to ensure uniformity and hence maintain quality. This process should be repeated at least a number of times until the grain reached 13% moisture content or less.

2.9 WINNOWING

Threshed rice contains impurities like chaff, straw, broken seeds, empty grains, stones, ball of earth, other crop seeds etc. Seeds should be immediately cleaned after harvesting prior to storage. The simple traditional cleaning method is winnowing, which uses the wind or a fan to remove the light elements from the grain. Mechanical winnowers that incorporate a fan and several superimposed reciprocating sieves or screens are also now in use in many countries including West African Countries.

2.10 STORAGE

Storability of seeds is mainly a genetically regulated trait which is influenced by the seed quality at the time of storage, history of seed before storage (environmental factors during pre and post-harvest stages), moisture content of seed, ambient relative humidity and temperature of storage environment, storage period and biotic agents (Shelar *et al*., 2008; Baleševiæ-Tubic *et al*., 2005; Khatun *et al*., 2009; Biabani *et al*.,2011). Damage of seed during storage is inevitable (Balesevic-Tubic *et al*., 2005). Seeds undergo deterioration during storage with the rate dependent on storage temperature, moisture and storage period (Ellis and Roberts, 1980).

These environmental conditions are very hard to maintain during storage. The seed storage environment highly influences the period of seed survival. After planting of deteriorate seeds, seedling emergence may be poor and transmission of pathogens to the new crop may occur. Lower temperature and humidity result in delayed seed deteriorative process and hence prolonged viability period (Mohammadi *et al*., 2011).

Rice seeds in storage respire by expending nourishment, consuming oxygen and generating carbon dioxide, water vapour and heat. This ideal condition may speed up the activity of insects and mould, which might enable them to generate more moisture and heat. Rice seeds stored at high moisture content tend to increase respiration, promoting heat generation by respiration which in turn causes secondary degeneration of rice (Wimberly, 1983).

Rice seeds to be stored for longer period must have moisture content less than 13-14%, must be protected from insects and rodents and from absorbing moisture through the surrounding atmosphere. Traditionally, grains including rice are kept in 40-50kg sacs which are made from jute or woven plastic. These bags should be kept under a shed and must be fumigated periodically to control insects. Some farmers use granaries which are made from timber, mud, cement or large woven baskets and these also suffer from insect and rodent damage.

2.10.1 Effect of Ambient Storage on Seed Quality

In the developing countries globally, farmers are still storing their produce including seed under ambient environment FAO (1981).Serious losses of viability have been documented from areas believed to have suitable climate for the production and storage of seed Basu (1995).In addition, Chin (1988) started that storage under ambient conditions has been reported to affect seed quality in general and germination in particular. In tropical areas, such as Brazil, ambient storage temperatures are observed above 20 °C indicating a more alarming decrease in germination (Dhingra *et al*., 1998)

2.11 SEED QUALITY

Seed quality is one of the major factors that determines the success or failure of a crop. It is of great agronomic and economic concern, and its importance in crop production cannot be overemphasized. The availability, access, and use of quality seed of adaptable crop varieties, are critical in increasing agricultural productivity, ensuring food security, and improving farmers livelihoods. Maintaining seed quality is essential if the variety is to meet the expectation of farmers and consumers. Mbora *et al*. (2009) reported that seeds of the best quality will result in crops of the best quality in the field which will result to yields of the highest value.

Quality seed can be defined as seed of an improved variety which has varietal and physical purity, low moisture content, high germination and vigour, free from weeds and seed-borne pathogens, uniform, and properly processed for distribution to farmers (van-Gastel *et al.,* 1996).

Earlier, Ellis (1992) indicated that seed quality is a broad term which encompasses several factors: seed health, varietal and physical purity, germination, vigour and sizes. Rickman *et al*. (2006) reported that the quality of the seed was very important to farmers as it measures the potential performance of the seed under optimal conditions. Since high quality seed is free from various diseases and has better seed health, it is expected to produce healthy seedlings with no initial disease inoculums (Nguyen, 2001). A superior quality seed not only increases productivity per unit area, but it also helps produce uniform crops without any admixtures, important for obtaining high prices on the market.

Seed quality is highly affected by harvesting and handling methods (Jyoti and Malik, 2013). Rickman *et al.* (2006) reported that seeds of high quality contain minimum impurities and as such have high establishment rates in the field.

Harvesting methods, threshing operation and type of cylinder play a major role on the amount of rice losses and quality (Alizadeh and Bagheri, 2009). Seed companies maintain quality using seed quality tests to monitor seed from harvest to purchase (McDonald, 1998).The seed quality tests must be reproducible and correct. The main methods used in seed testing include: sampling, analytical purity, germination capacity, viability, vigour, moisture content, weight determination and varietal purity (ISTA, 2007).

In Ghana, however, in common with most developing countries, rice and other cereal seed production is in the hands of many small-scale producers (Lyon and Afikorah-Danquah, 1998), who cannot afford the cost of cold storage, even where available. This means that seed producers and individual farmers have to store their own seed and maintain its viability and vigour in storage until the next cropping season. Such seeds are often stored in inappropriate storage materials under ambient and fluctuating temperature and relative humidity conditions. Poorly stored seed will therefore result in poor seed quality leading to poor stand establishment, low seedling vigour and low grain yield (McDonald, 1998).

2.11.1 Seed Quality Component

There are many aspect of seed quality that can immensely affect the crop (van-Gastel *et al.*, 1996). Paramount amongst them include: moisture content, analytical purity, germination and vigour which includes 1000seed weight, seedling emergence and conductivity.

Moisture content**:** The most common physical characteristic of seed rice quality is the moisture content. Biological activity occurs only when moisture is present. Therefore, moisture content of the product itself, as well as the moisture content of the surrounding air, is important for safe storage (Hayma, 2003). Higher temperature and moisture content values of grains favour insect and fungus development and a decline in the germination capacity of the grains (Hayma, 2003). (Dilday, 1987), showed that the amount damaged grain is significantly affected by moisture content and speed of cylinder. Increasing cylinder speed from 600 to 1000 rpm, increases the grain damage by twofold. Also grain damage decreased with an increase in grain moisture content.

To some extent the lower the moisture content the better is the quality. The moisture content will strongly determines the length of preservation, wherever is it being stored. The higher the moisture content and storage temperature, the shorter is the storage duration. In contrast, lower moisture content in combination with lower storage temperature will improve the time limit of preservation (Kuo, 2009). Seeds undergo deterioration during storage with the rate dependent on storage temperature, moisture and storage period (Ellis and Roberts, 1980).

Analytical purity**:** Analytical purity is defined as the proportion of pure seed and the composition of the undesired matter in in a seedlot (van- Gastel *et al.*, 1996). This is done to determine the percentage composition by weight of the sample being tested and by reference the composition of the seedlot (Agrawal and Dadlani, 1995). In other words, the composition of the sample is ascertained and the results are expressed as weight percentages.

Analytical purity is done to determine the identity of various species of seeds and inert matter constituting the sample (Agrawal and Dadlani, 1995, ISTA, 2007). According to Eskandari (2012), seeds in the lot must be uniform in size, less diseased and damaged and with minimum weed seeds or inert matter. Agrawal and Dadlani, (1995) stated that it is not totally possible to remove all the admixtures with the use of cleaning machine. Dadalani *et al*. (2003) reported that quality seed is important for good plant stand and high yield. Care is needed not only in selecting a suitable variety but also in using seeds having high levels of purity, germination and sanitation.

Germination: With regards to seed quality control programmes, germination can be defined as the emergence and development of the seedling to a stage where the presence, absence and formation of the essential structures can be assessed, thus indicating whether or not the seedling is able to develop further in to a satisfactory plant under a favourable conditions in the soil (Anonymous, 1985). However, not all germinable seeds necessarily produce normal seedlings (Agrawal and Dadlani, 1995). Moreover, in seed laboratory practice, germination is defined as the emergence and development from the seed embryo of those essential structures which for the kind of seed in question, are indicative of the ability to produce a normal plant under favourable conditions (AOSA, 1981).

Evaluation of germination test**:** Germination test needs to be evaluated on the expiry of the germination period, which varies according to the kind of seeds. However, the seed analyst may terminate the germination test on or before the final count day or extend the test beyond the period depending on the situation (STPP, 2014). In evaluating the germination test, the seedling and seeds are categorized in to the following according to ISTA, (2007).

Normal Seedlings**:** Seedlings which show the capacity for continued development into normal plant, when grown in good quality soil and under favourable conditions of water supply, temperature and light. Seedlings that possess all the following essential structures when tested on artificial substrata:

To achieve uniformity in evaluating normal seedlings, they must conform to one of the following definitions:

i) A well-developed root system in which the primary root is intact or shows acceptable defects; discoloured or necrotic spots, healed cracked or splits and superficial cracks or splits. Seedlings with a defective primary root are classed as normal, if sufficient normal secondary roots have developed.

ii) In the shoot system, a well-developed mesocotyl is intact or shows acceptable defects; discoloured or necrotic spots, superficial cracks or splits and loose twists.

iii) An intact coleoptile or shows acceptable defects; discoloured or necrotic spots, loose twists or a split of one third or less from the tip.

iv) The primary leaf is intact, emerging from the coleoptile near the tip or shows acceptable defects; discoloured or necrotic spots, slightly retarded growth.

Abnormal Seedlings: Seedlings which do not show the potential to develop into a normal plant when sown in a good quality soil and under a favourable condition of moisture, temperature and light. Seedling with cracked or split essential structure as a result of mechanical damage during harvest and processing may result to abnormal seedling provided the conductive tissues did not heal (ISTA, 2003)

A seedling is abnormal if it is; deformed, fractured, consist of fused twin seedlings, yellow or white, spindy, glassy or decayed as a result of primary infection.

i) The root system consisting the primary root is defective if it is; stunted or stubby, retarded or missing, broken or split from the top, shows negative geotropism, constricted, spindy, glassy or decayed as a result of primary infection. Seedlings with a defective primary root are classed as normal, if sufficient normal secondary have developed.

ii) The shoot system;- the developed mesocotyl is defective if it is; cracked or broken, forming a loop or spiral, tightly twisted or decayed as a result of primary infection

iii) The coleoptile is defective if it is; deformed, broken or missing, has a damaged or missing tip, strongly bent over, forming a loop or spiral, tightly twisted, split for more than one third from the tip, split other from the tip, spindy or decayed as a result of primary infection.

iv) The primary leaf is defective if it; extends less than half the length of the coleoptile, is missing, is deformed, yellow or white or decayed as a result of primary infection.

In Oryza sativa, the first structure to show up at the start of germination is the coleoptile, followed by the primary root later. The final length of the coleoptile is comparatively short, though it may vary somewhat, depending on the variety and the test conditions. When the first leaf penetrates the coleoptile it opens by the slit near the end and is gradually split further down by the emerging leaf. Yet the basic part of the coleoptile remains closed and sheath-like, otherwise the seedling is considered abnormal. The first leaf consists of a leaf sheath only and remains tightly rolled. Only the second leaf, coming up through the first one, possesses a real leaf blade.

The root system consists of a primary root and numerous secondary roots including lateral and adventitious roots (ISTA, 2003).

Seed vigour**:** Seed vigour is the sum of those properties that determine the activity and performance of seedlot of acceptable germination in a wide range of environment (ISTA, 2007). Several other factors such as environmental conditions during seed producing stage, pest and diseases, seed oil content, storage longevity, mechanical damages of seed during processing, fluctuations in moisture (including drought), weathering, nutrient deficiencies, packaging, pesticides, improper handling, drying and biochemical injury of seed tissue can affect vigor of seeds (Krishnan *et al*., 2003; Marshal and Levis, 2004; Astegar *et al*., 2011; Simic *et al*., 2007).

Vigour tests are done to provide;

i) A more sensitive index of seed quality than the standard germination test
ii) A consistent ranking of seedlots of acceptable germination in terms of their potential, physiological and physical quality.
iii) Information on emergence and storage potential of seedlot to plan marketing strategy (ISTA, 2007).

However, many vigour tests were initially developed empirically to give a clear insight on the basis of seed aging (Agrawal and Dadlani, 1995). These include physical test (seed size weight and volume), physiological test (standard germination, seedling evaluation, stress test eg cold test), biochemical test (conductivity test, Tetrazolium test) and aging test (accelerated aging and controlled deterioration) (Agrawal and Dadlani, 1995).

1000 seed weight**:** According to ISTA (2007), seed weight refers to the weight of 1000seeds obtained from the pure seed weight fraction. Seed weight can be affected by seed size, moisture content and degree of processing (Introduction to seed testing). Msuya and Stefano (2010) stated that, grain size reflects the quantity of food reserves and physiological biosynthates that can be available to support growth during germination and seedling establishment. Msuya and Stefano (2010) also reported that smaller seeds can germinate more rapidly. However, larger seeds establish their root and shoot systems more quickly after germination so that they are able to absorb nutrients with in their reach and photosynthesize food that is assimilated for growth. Mahadevappa and Nandisha (1987) indicated that heavier seeds produce vigorous seedlings responsible for high grain yields. It has been concluded that the thousand (1,000) seed weight is a useful tool in calculating the seeding rates and harvest loses Anon (2007). Variation in seed mass may have distinct consequences for seed germination and seedling Survival (Ruiz de Clavijo 2002, Du and Huang 2008, Parker *et al*., 2006).

First seedling count: This is done along with the regular germination test. The number of normal seedlings, germinated on the first count day, as specified in the germination test for each species, is counted. The number of normal seedlings gives an idea of the level of seed vigour in the sample. The faster and higher the sprouting of normal seedlings, the greater the seed vigour is.

Seedling Vigour Index: For evaluation of seed and seedling vigor, 10 normal seedlings were selected randomly from each replication after standard germination test and shoot and radicle length were measured by ruler in cm. Seedling vigor index was calculated by below relation (Abdul- baki and Anderson, 1973).

Seedling Vigor Index= (the mean primary radicle length + the mean of first shoot length) × final germination percent.

Conductivity test**:** Seed electrical conductivity measurement is used for seed vigour test of many crop species (Sheidaei *et al.*, 2014). This test was designed to identify solute leakage due to decrease membrane integrity and tissue death during aging of seed (Agrawal and Dadlani, 1995). However, as seed deterioration progresses the cell membranes become weak and allows cell content to exit in to solution thereby increasing it electrical conductivity (ISTA, 2007). Seedlot with low electrolyte leakage and low conductivity reading is considered as having high vigour. Conversely, those with high electrolyte leakage and high conductivity readings are considered as having low vigour (ISTA, 2007).

2.12 FACTORS AFFECTING SEED QUALITY

Several factors affect seed quality paramount amongst them include seed moisture content, temperature and relative humidity, mechanical damage and insects and mite.

2.12.1 Seed Moisture Content

Seed moisture is one of the most important factors affecting loss of seed quality in tropical and subtropical countries (STSQCA, 2007). The amount of water in seed affects the amount of damage during threshing, drying, cleaning and storage– cracking, bruising, drying moisture gradients, handling, seed respiration and insect and mould growth (STSQCA, 2007). The moisture content of seed during storage is the most persuasive factor affecting the longevity. Storing seeds at high moisture content enhances the risk of quicker deterioration at shorter time. Seeds are hygroscopic in nature; they can pick up and releases moisture from and to the surrounding air. They absorb or lose moisture till the vapor pressure of seed moisture and atmospheric moisture reach equilibrium (Shelar *et al*., 2008).

To prevent the above, seed moisture content should be kept low. Conversely, keeping seeds at extremely low moisture content should be avoided because it will render some seed species to breakage during processing and transporting and in some way may induce dormancy (Muliokela, 1995). Humid conditions can lead to increase in seed moisture content and hence reduced shelf life (Santos, 2007). So a moisture test taken today may bear little relevance to the moisture of the same seed lot some days or weeks later.

2.12.2 Temperature and Relative Humidity

Seed longevity is markedly affected by relative humidity and storage temperature (Muliokela, 1995). .The lower the temperature, the lower the rate of respiration and thus the longer the shelf life. High temperature accelerate the rate of biochemical processes causing more rapid deterioration that resulted in rapid losses in seed having high moisture content (Shelar *et al*., 2008). Sensitivity of seeds to high temperatures is vehemently dependent on their water content, loss of viability being quicker with increasing moisture content (Kibinza *et al*., 2006). Temperature is crucial because it influences the amount of moisture and also enhances the rate of deteriorative reactions occurring in seeds as it increases. For seeds to maintain their quality during storage, temperature should be reduced (Eskandari, 2012). Control of relative humidity is the most important because it directly influences the moisture content of seeds in storage as they come to equilibrium with the amount of moisture surrounding them; a concept known as equilibrium moisture content. The lower the moisture content, the longer seeds can be stored provided that the moisture level can be controlled all through the storage period.

2.12.3 Mechanical Damage

This is also known as quality loss, this is the percentage of seed damage in form of breakage which occurs during threshing and milling, breakages considerably reduce the market value of the grain (Sheidaei *et al.*, 2014).

The main effect of mechanical damage is decrease of germination and yield (Grass & Tourkmani, 1999). Mechanical damage is one of the causes of great loss of seed quality in tropical and subtropical environments. Developing cultivars that are less susceptible to mechanical damage is an important contribution from the breeders to the soybean growers for overcoming this limitation in addition to improving grain quality by reducing the amount of splits and cracks (Krzyzanowski, 1998). Khazaei (2009) mentioned that, soybean seeds especially during threshing undergo sever pressures of metal elements of harvest machines which results in broken seeds, seed coat cracks and also invisible internal damage. The extent and type of damage depend not only on the threshing machine designing properties and effectiveness but also on the threshing conditions and cultivar properties (Sosnowski and Kuzniar, 1999, Khazaei *et al.*, 2009). The extent of damage in seeds is a complex interaction that involves some parameters that affect final quality of seed such as seed moisture content, impact velocity, cultivar of seed, seed size and loading times (Khazaei *et al.*, 2007).

Dubbern *et al.* (2001) remarked that seeds with damaged seed coat usually have less vigor and viability. Jahufer and Borovoi (1992) reported that in maize mechanical damage to seed coat decreased seed germination, seedling growth and development and grain yield. Seedling emergence and quality is affected by the place of damage in a way that embryo and central parts of seed are more susceptible (Jahufer and Borovoi, 1992). Rahman *et al.* (2004) at their research observed the mechanical damage cause seed vigor reduction. Mechanical damage is one of the major causes of seed deterioration during storage (Jyoti and Malik, 2013). Damaged grains pose less resistance against pests and diseases and have the minimum storage life (Salari *et al.*, 2013). Additionally, broken grains impair germination ability (Spokas *et al*., 2008). (Dilday, 1987), showed that the amount damaged grain is significantly affected by moisture content and speed of cylinder. Increasing cylinder speed from 600 to 1000 rpm, increases the grain damage by twofold. Also grain damage decreased with an increase in grain moisture content.

2.12.4 Effects of Organisms Associated with Seeds

Organisms associated with seeds in storage are bacteria, fungi, mites, insects and rodents. The activity of these entire organisms can lead to damage resulting in loss of vigor and viability or, complete loss of seed (Jyoti and Malik, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Field and laboratory research locations

The field research was conducted from July to December, 2014 at the lowland irrigated rice field located at Nobewam, near Konongo in the Ashanti Region of Ghana. The area lies between latitudes 6^{o} 35' to 6^{o} 54' N and longitudes of 1^{o} 4' to 1^{o} 23' W. The valley within which rice is cultivated is within an elevation of 180m to 200m and the width of 160m to 1000m. This area has a bimodal rainfall pattern which ranges between 1300 to 2200 mm per annum (Asante *et al*., 2013). The laboratory study was carried out in the Quality Control Unit Laboratory at the Grains and Legumes Development Board, Kumasi, in the Ashanti Region of Ghana.

3.2 Experimental design

The design was 3 x 3 factorial arrangement in RCBD with three replications. The factors were variety at three levels: Jasmine-85, Nerica-L41 and Sikamo; threshing methods at three levels: Box, (Bambam), Drum and Machine.

3.3 Experimental Procedure

Three varieties of rice namely: Jasmine-85, Nerica L-41 and Sikamo were obtained from CSIR-Crops Research Institute, Kumasi, Ghana. Seed beds were prepared 14 days before sowing. Weeds and volunteer crops were cleared before the beds were seeded. Seeds (500 grams from each source) were pre-germinated and sown by broadcasting on a wet nursery bed. Seeds from each source were sown in a nursery plot measuring 10 m x 2 m. The land was sprayed with Sunphosate (410g/litres glyphosate) at the rate of 5 litres/hectare. The field was ploughed seven days after herbicide application. Transplanting was done 14 days after the field was ploughed and harrowed. Seedlings were planted in plots at a planting distance of 20cm x 20cm. Fourteen days after transplanting, 60-60-60 kg/ha (8.32kg/plot) of NPK (15-15-15) was applied by broadcasting. 60kg (N)/ha (2.71kg (Urea)/plot) was applied at panicle initiation. All other recommended agronomic practices such as weed control, pest and disease control and water management were carried out until harvesting. Each variety was harvested with a sickle when the rice was at physiological maturity with a grain moisture content of 20 - 22 %. After harvesting, the paddies were packed by varieties for threshing.

3.4 Threshing

Threshing was carefully done in order to reduce the risk of damaging the seeds or contaminating them with disease or mixing them with other varieties. Therefore, the threshing area was properly cleaned and covered with tarpaulin. The three threshing methods were then applied to 600kg of harvested seeds of each of the varieties (Plates 3.1, 3.2 and 3.3). One variety was threshed at a time and the threshing equipment and environment properly cleaned. The time for threshing was recorded by a stopwatch and the threshed paddy weighed. The threshed paddies from each treatment were collected in bags and labeled.

Plate 3.1: Rice threshing using Bambam (Box) method

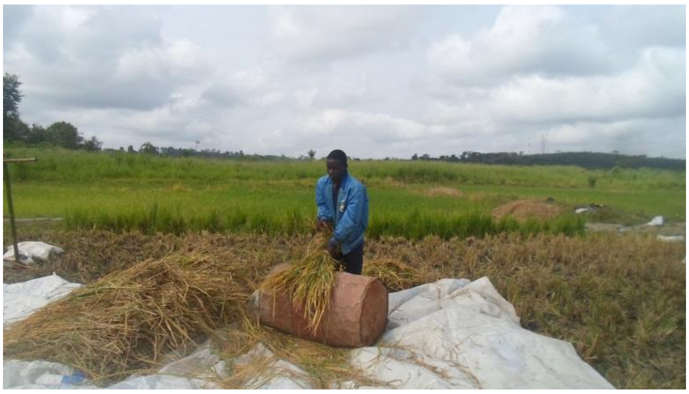

Plate 3.2: Rice threshing using metal drum (Barrel method)

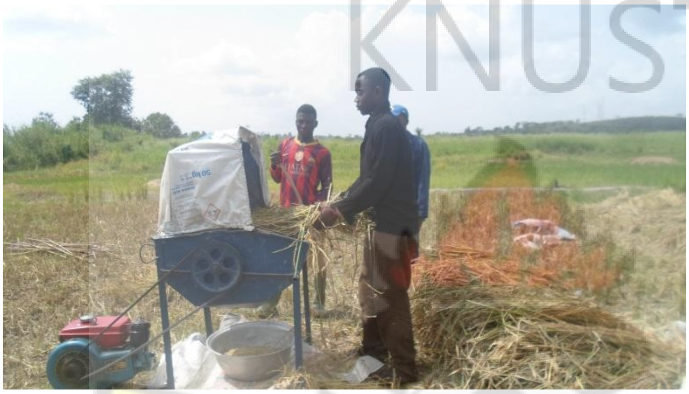

Plate 3.3: Rice threshing using Machine

3.5 Winnowing and determination of broken and husked rice

This was done with the aim of cleaning the seeds, ie, getting rid of impurities-straws, insects and stones. Each treatment was separately winnowed using a mechanical winnower. After winnowing one variety, the winnower was properly cleaned to avoid adulteration. The winnowed seeds were placed into their respective containers for drying.

The percentages of broken and husked grains were determined after each threshing treatment. Three samples of 100g rough rice was taken from the outlet of the thresher for each treatment and then the broken and husked grains separated manually and weighed (Srivastava *et al*., 1998).

3.6 Drying

The paddy was dried in an open air on the concrete floor. Drying was done for 4 hours per day for a period of two days. The paddy rice was spread into thin layers on the drying floor by treatments and regularly turned and stirred using a rake. This was done to distribute moisture more evenly and increase the rate of drying. For this study, the paddy was dried to a moisture content of 10 % to 13 %. The samples were packaged into polythene bags which had been pre-treated by immersing in boiling water for 15 to 20 minutes and sun-dried.

3.7 Storage

The moisture content of the respective treatments was recorded using a Gann Hydromette G 86. Three replicates of 5kg per each treatment were weighed and placed into the treated bag. At zero storage, samples of each treatment were collected for analysis. For storage, the containers were placed on wooden crates for a period of 4 months in a room. The temperature and relative humidity readings of the storage environment were recorded daily for the period of four months. A Lascar Microdag Humidity and Temperature Data logger was used to record the readings.

3.8 LABORATORY EXPERIMENT

The treatments were varieties at 3 levels (Nerica L-41, Jasmine 85 and Sikamo) and threshing methods at 3 levels (bambam or box, barrel and machine thresher) arranged in CRBD with three replications.

3.8.1 Sampling Procedures in the Laboratory

Each sample was reduced into a working sample for analysis as stated by Agrawal and Dadlani, (1995) and then thoroughly mixed by passing it through a Boerner divider. The sample was reduced repeatedly by pouring the seed through the divider and removing one half on each occasion. The process of successive halving continued until the working sample of the required size was obtained. The following laboratory analyses were performed; moisture content, analytical purity, standard germination test, seed vigour (Conductivity test), seedling vigour and 1000 seed weight.

3.8.2 Data Collected

3.8.2.1 Moisture Content determination

Moisture tests were done at the respective sampling times. Estimate of moisture content was made by loss in weight when seed samples were ground and dried in an air oven at a high constant temperature as recommended in the ISTA (2007). Three replicates, each of 5 grams, were ground and kept for two hour in an open air oven at 130º C. The samples were then placed in desiccator for 30 minutes to cool. The percentage moisture loss in drying was calculated as follows;

$$\textbf{\% moisture} = \frac{M2\text{-}M3}{M2\text{-}M1} \times 100$$

Where,

M1 = weight in grams of the container and its cover.

M2 = weight in grams of the container, cover and its contents before drying.

M3 = weight in grams of the container, cover and content after drying.

3.8.2.2 Seed Purity analysis

A working sample was drawn from the submitted sample, weighed and separated into three components: pure seed of the test species, seed of other species, and inert matter. Each component must then be weighed and recorded in grams.

Calculation of the purity analysis was done as follows:

$$\% \text{ of pure seed} = \frac{\text{Weight of pure seeds}}{\text{Total weight of sample}} \text{ x } 100$$

$$\% \text{ of other crop seed} = \frac{\text{Weight of other crop seed}}{\text{Total weight of sample}} \text{ x } 100$$

$$\% \text{ of inert matter} = \frac{\text{Weight of inert matter}}{\text{Total weight of sample}} \text{ x } 100$$

3.8.2.3 Seed germination test

Four replications of 100 seeds were drawn from each treatment of pure seeds. The seeds were pressed in to the surface of the sand in the germination trays. The first seedling count was done on the fifth day and the final count on the fourteenth day as described in the ISTA rules for seed testing (ISTA, 2007). At the end of the germination tests, the percentage of normal seedlings, abnormal seedlings, fresh and ungerminated seeds hard seeds and dead seeds were evaluated and recorded in line with criteria set by (ISTA, 2007).

$$\text{Germination\%} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds sown}} \text{ x } 100$$

3.8.2.4 1000 Seed weight determination

Eight replicates of 100 seeds were drawn randomly from the purity seed fraction of the purity test and then recorded. The mean weight of the 8 replicates was calculated and multiplied by 10 following the procedure for 1000 seeds weight determination as described (ISTA, 2007).

3.8.3.5 Seed electrical conductivity test

Four replications of 50 undamaged seeds of each treatment were weighed to 2 decimal places and moisture content recorded. The seeds of each replication were placed in 200ml beaker and 75 ml of deionized water was added. The seeds were stirred gently to ensure that all seeds were completely immersed and evenly distributed. The beakers were covered by aluminum foil to reduce contamination. The beakers were placed at the constant temperature of 20ºC for 24 hours. The electrical conductivity of the leachates of each replication was measured by using a conductivity meter (EUTECH PC 700) and conductivity per gram of seed weight was calculated ($\mu Scm^{-1}\ g^{-1}$) and recorded as per ISTA. (2007).

$$\text{Conductivity } (\mu S\ /cm/g\ ) = \frac{(\text{Conductivity reading-Blank reading})}{\text{Weight (g)of replicate}}$$

3.8.2.6 Seedling vigour test

Ten normal seedlings were selected randomly from each replication after standard germination test and shoot and radicle length were measured by ruler in cm. Seedling vigor index was calculated as below:

Seedling Vigor Index= (the mean primary radicle length + the mean of first shoot length) × final germination percent. (Abdul- baki and Anderson, 1973).

3.9 DATA ANALYSIS

Data collected from the laboratory experiments was subjected to analysis of variance using Statistix Student Version 9.0. LSD (Least Significant Difference) was used for mean separation at probability level of 0.05 and 0.01 for broken seeds and laboratory experiments, respectively.

CHAPTER FOUR

4.0 RESULTS

4.1 Percent moisture content of rice before storage

There were significant differences among the varieties for percent moisture content before storage (Table 4.1). Nerica-L41 had the highest (11.41%) moisture content while Jasmine-85 had the least (10.29%). The moisture content of Sikamo (10.46) was similar to that of Jasmine-85.

Table 4.1 Effect of Variety on Moisture content (%) before storage

Varieties	Moisture content (%)
NERICA-L41	11.41
JASMINE -85	10.29
SIKAMO	10.46
LSD (0.01)	0.287

4.2 Seed germination before storage

There were significant varieties x threshing methods interactions for seed germination before storage (Table 4.2). Sikamo threshed using machine recorded the highest (88.83%) germination, significantly higher than Sikamo threshed using box which recorded the lowest (62.67%). Amongst the varieties, there were no significant differences. Also among the threshing methods, there were no significant differences.

Table 4.2 Effects of varieties and threshing methods on percent germination of rice seeds before storage.

Percent germination				
Varieties	**Threshing Methods**			Mean
	BOX	BARREL	MACHINE	
NERICA-L41	81.67	81.67	74.00	79.11
JASMINE -85	82.00	78.33	79.00	79.78
SIKAMO	62.67	83.33	88.33	78.11
Mean	75.44	81.11	80.44	

LSD (0.01): Variety =6.308 ; Threshing Method = 6.308;

Variety x Threshing Method=10.925.

4.3 Seed conductivity before storage

Significant variety x threshing methods interactions were found for seed conductivity before storage (Table 4.3). Sikamo threshed using machine recorded the highest (11.32µS/cm/g) conductivity value while Sikamo threshed using the barrel recorded the lowest (1.63µS/cm/g). Among the varieties, there were no differences in the conductivity values. For the threshing methods however the conductivity value resulting from the use of machine was significantly higher than those for box and barrel threshing methods (Table 4.3).

Table 4.3 Effect of Variety and Threshing method on seed conductivity before storage.

	Seed Conductivity (µS/cm/g)			
Varieties	**Threshing Method**			Mean
	BOX	BARREL	MACHINE	
NERICA-L41	6.05	4.86	4.43	5.11
JASMINE -85	3.09	8.43	6.29	5.94
SIKAMO	4.80	1.63	11.32	5.92
Mean	4.64	4.97	7.35	

LSD (0.01): Variety = 2.412; Threshing Method = 2.412;

Variety x Threshing Method=4.177.

4.4 1000 seed weight before storage

There were significant varieties and threshing methods interaction for 1000 seed weight (Table 4.4). The highest value was recorded by Jasmine-85 threshed using machine (27.94g) and the lowest by Jasmine-85 threshed using barrel (26.18g). Similarly, significant differences were recorded among the varieties for 1000 seed weight. Nerica-L41 had the highest (27.33g), while Sikamo recorded the lowest (26.72g). Threshing methods also differed significantly such that machine threshing recorded the highest (27.08g) and barrel threshing the least (26.74g) (Table 4.4).

Table 4.4 Effect of Variety and Threshing method on 1000 Seed Weight (g) before storage.

	1000 Seed Weight (g)			
Varieties	**Threshing Method**			Mean
	BOX	BARREL	MACHINE	
NERICA-L41	27.65	27.46	26.58	27.23
JASMINE -85	26.68	26.18	27.94	26.93
SIKAMO	26.86	26.58	26.73	26.72
Mean	27.06	26.74	27.08	

LSD (0.01): Variety = 0.127; Threshing Method = 0.127;

Variety x Threshing Method=0.220.

4.5 Percent broken seed before storage

There were significant differences among the threshing methods for broken seeds (Table 4.5). Machine threshing recorded the highest percentage of broken seed (0.96%). The lowest percentage was recorded by box threshing (0.43%).

Table 4.5 Effect of Threshing Method on Broken Seeds (%) before storage

Threshing Methods	**Broken Seeds (%)**
BOX	0.43
BARREL	0.61
MACHINE	0.96
LSD (0.05)	0.157

4.6 AMBIENT CONDITIONS OF STORAGE ENVIRONMENT

Temperature ranged between 28.97 ºC and 30.04 ºC. Relative humidity ranged from 66.76% to 71.83%. The minimum temperature was observed in December 2014 and the maximum in March, 2015. The minimum relative humidity was observed in February, 2015 and the maximum in March, 2015.

Table 4.6 Average temperature and relative humidity in the storage environment

Months	Temperature ºC	Relative Humidity %
December	28.97	69.94
January	29.50	68.85
February	29.33	66.76
March	30.04	71.83

4.7 Effect of variety on percent moisture content after storage

There were significant differences among the varieties for moisture content after storage (Table 4.7). Nerica-L41 recorded the highest moisture content (11.6 %). The lowest moisture content was recorded by Jasmine-85 (10.5 %) though not significantly different from Sikamo (10.8 %).

Table 4.7 Effect of Variety on Moisture content (%) after storage.

	Moisture content (%)
Varieties	**Moisture content (%)**
NERICA-L41	11.6
JASMINE -85	10.5
SIKAMO	10.8
SD (0.01)	0.37

4.8 Effect of variety on seed conductivity after storage

Significant differences were recorded among the varieties for seed conductivity after storage (Table 4.8). Nerica-L41 after storage recorded the highest conductivity value (8.15µS/cm/g) whereas, Sikamo after storage recorded the lowest conductivity value (6.26µS/cm/g).

Table 4.8 Effect of Variety on Seed Conductivity (µS/cm/g) after storage

Varieties	Seed Conductivity (µS/cm/g)
NERICA-L41	8.15
JASMINE -85	7.72
SIKAMO	6.26
LSD (0.01)	1.093

4.9 Effect of threshing method on seed conductivity after storage

Amongst the threshing methods, significant differences were recorded for seed conductivity after storage (Table 4.9). Box threshing method recorded the highest conductivity value (8.11µS/cm/g) while the lowest conductivity value was recorded on barrel method (7.02µS/cm/g) which was not significantly different from machine method.

Table 4.9 Effect of Threshing Method on Seed Conductivity (µS/cm/g) after storage.

Threshing Method	Seed Conductivity (µS/cm/g)
BOX	8.11
BARREL	7.00
MACHINE	7.02
LSD (0.01)	1.093

4.10 Effects of variety and threshing method on percent germination of seed after storage

There were significant variety and threshing methods interactions for percent seed germination after storage (Table 4.10). Jasmine-85 threshed using machine recorded the highest percent germination (89.0 %) whilst Sikamo threshed using machine recorded the lowest germination (75.0 %). Amongst the varieties, there were no significant differences. Similarly, among the threshing methods, there were no significant differences (Table 4.10).

Table 4.10 Effect of variety and threshing method on percent seed germination after storage.

	Seed germination (%)			
Varieties	**Threshing Method**			Mean
	BOX	BARREL	MACHINE	
NERICA-L41	86.08	85.00	84.58	85.22
JASMINE -85	78.00	80.00	89.00	82.33
SIKAMO	88.00	84.67	75.00	82.56
Mean	84.03	83.22	82.86	

LSD (0.01): Variety =5.341; Threshing Method = 5.341; Variety x Threshing Method=9.251.

4.11 Effect of variety on seedling vigour index after storage of seeds

There were significant differences among the varieties for seedling vigour index after storage of seeds (Table 4.11). Sikamo recorded the highest seedling vigour index (2452.7). The lowest seedling vigour index was recorded by Jasmine-85 (2207.5) though not significantly different from the seedling vigour index of Nerica-L41.

Table 4.11 Effect of Variety on Seedling Vigour Index after storage.

Varieties	Seedling Vigour Index
NERICA-L41	2386.1
JASMINE -85	2207.5
SIKAMO	2452.7
LSD (0.01)	213.95

4.12 Effects of variety and threshing method on 1000 seed weight after storage

Significant difference was recorded on the variety and threshing methods interaction for 1000 seed weight after seed storage (Table 4.12). Jasmine-85 using machine threshing resulted in the highest 1000 seed weight (28.90g) whilst Nerica-L41 using machine threshing recorded the lowest (26.72g).

Table 4.12 Effect of variety and threshing method on 1000 Seed Weight (g) after storage.

	1000 Seed Weight (g)			
Varieties	**Threshing Method**			Mean
	BOX	BARREL	MACHINE	
NERICA-L41	28.09	28.08	26.72	27.63
JASMINE -85	27.29	27.08	28.90	27.76
SIKAMO	27.66	26.8	27.35	27.29
Mean	27.68	27.34	27.65	

LSD (0.01): Variety = 0.515; Threshing Method = 0.515;

Variety x Threshing Method=0.893.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effects of variety and threshing methods on broken seeds, seed germination and seed conductivity before and after storage

Before storage, machine threshing recorded the highest percentage of broken seeds whilst box threshing recorded the lowest. This could be attributed to the threshing surface of the machine which composed of wire loops or peg-tooth fixed to the rotating drum or cylinder. During threshing, the paddy straw is held against the rotating drum or cylinder and the impact created stripped off the spikelet from the panicles at a higher speed resulting in cracks or broken seeds (Harrison 1992; Bourgeois 1993). The low percentage of broken seeds using the box threshing method could be attributed to the wooden threshing surface which cushioned the threshing impact and therefore reduced the occurrence of seed breakage. Alizadeh and Bagheri (2009) indicated that the threshing method employed had a significant effect on grain losses namely; broken and cracked rough rice. Miah *et al.,* (1994) also stated that the percentage of grain damage is significantly affected by the threshing method used. Similar findings were also reported by Siebenmorgan *et al.,* (1998); Nyugen and Kunze, (1984) and Banaszek and Siebenmorgan (1990).

Jasmine-85 threshed using machine recorded the highest germination while Sikamo threshed using machine recorded the lowest (74.67%) seed germination after storage. Jasmine-85 is a fragile variety (Hagrove, 1997) and therefore only minimal threshing force is needed to cause dislodging of the grain from the spikelet. This therefore implies that very minimal damage might have been caused to the embryo, resulting in the high germination of the seeds after storage. On the contrary, Sikamo variety is difficult to thresh and therefore the threshing action of the machine might have caused fissures along the embryo (Ragasa *et al*., 2013), resulting in the damage to the embryonic axis and subsequently affecting seed germination (Jahufer and Borovoi, 1992). The box threshing method due to its minimal force on the grains resulted in higher seed germination than the drum method which by the action employed created cracks and fissures on the grain with a resultant possible damage to the embryo.

Seed conductivity values differed significantly among varieties, threshing methods and their interaction. Among the varieties, Sikamo recorded the highest conductivity value. During threshing, Sikamo seeds underwent severe pressure on the metal element, wire loop or pegs fixed to the rotating drum of the thresher. The pressure created on the seeds as a result of the rotating drum speed, operating conditions and seed traits might have accelerated mechanical damage which resulted in crack seed coats, broken seeds and invisible internal damage ((Sosnowski and Kuzniar, 1999, Khazaei *et al.*, 2009). Fissure created during threshing might have allowed seed matter content to exit during seed conductivity test. Divsalar and Oskouie (2013) stated that the more the damaged the seeds are, the more exudation and the higher the rate of conductivity. Seedlots with high electrolyte leachate are considered as low vigour seeds whilst those with low leakage are considered high vigour seeds (ISTA. 2007).

Threshing using box reduces the severity of the cracks, fissures and seed coat damage thereby reducing the quantity of seed matter content that exit during seed conductivity test. Contrary to the values recorded before storage, an increase in conductivity values were recorded after storage. The increase in conductivity values might be due to injuries sustained during threshing which have been worsened by the storage environment (Rahman, 2004; Verasilpa *et al.*, 2001 and Dubbern, 2001).

5.2 Effects of variety and threshing method on 1000 seed weight

Before storage, thousand seed weight for the varieties varied from 26.18g to 27.94g. Nerica-L-41 recorded a higher 1000 seed weight as compared to Sikamo which had the least. This could be attributed to the genetic differences (St Clair and Adams 1991; Sorensen and Campbell, 1993). Mahadevappa and Nandisha, (1987) indicated that heavier seeds produced vigorous seedlings responsible for higher grain yield. Msuya and Stefano, (2010) also indicated that larger seeds established their root and shoot systems quicker after germination, so that they are able to imbibe, photosynthesize and assimilate nutrients required for growth. Species producing heavier seeds often exhibit seedlings with greater initial height with more chance to reach better light condition and survivorship (Parker *et al.,* 2006), while light seed plants usually have lower reproductive performance (Ribeiro *et al.,* 2012).

Thousand seed weight after storage varied from 26.72g to 28.90g. Seed weight after four months of storage was higher than those at zero storage. This could be due to moisture absorption by the seeds during storage as evidenced by the increase in moisture content of the varieties after storage. Similar findings were reported by Adu- Dapaah *et al.*, (2005), Nogueira *et al*., (2014) and Reddy and Charkraverty, (2004).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

From the results obtained, the following conclusions can be made:

Machine threshing recorded the highest percentage of broken seeds whilst box threshing recorded the lowest. Moreover, Jasmine-85 threshed using machine recorded the highest germination while Sikamo threshed using machine recorded the lowest seed germination after storage. Electrical conductivity values increased after storage although the values were still within the high seed vigour bracket. However, 1000 seed weight increased after storage due to moisture absorption by the seeds during storage.

6.2 RECOMMENDATIONS

i. The present study should be repeated using different threshers and varieties in different farming zones to generate more information on threshing effects on seed quality parameters.

REFERENCES

Abdul-baki, A. A. and Anderson, J. D. (1973). Vigor determination in soybean seed by multiplication. Crop Science **3,** 630-633. http://dx.doi.org/10.2135/ crop sci 1973 .0011183X0013.00060013x.

Adu-Dapaah, H. K., Asibuo J. Y., Asafo-Adjei, B., Dashiel, K., Amoah, S., Asafu-Adjei, J. N. and Addo, J. K. (2005). *Breeding Methodology, Botanical and Agronomic Characteristics of four Groundnut, Two Cowpea and two Soybean Genotypes Proposed for Release.* Pp. 42-60.

Agrawal, P.K. and Dadlani, M. (1995). Techniques in Seed Science and Technology. Second Edition. South Asian Publishers New Delhi International Book Company Absecon Highlands: 109–113.

Agropedia (2009). Botanical classification of Rice, http://agropedia .iitk.ac.in/ content /botanical-classification-rice, Submitted by naipictuasd harwad on Friday, 06/03/2009 - 12:51.

Ajav, E. A. and Adejumo, B. A. (2005). Performance Evaluation of an Okra Thresher. *Agric. Eng. Int.,* **VII**: 1-8.

Akintayo. I., Cissé, B. and Zadji, D.L. (2008) Guide pratique de la culture des NERICA de plateau. Centre du riz pour l'Afrique (ADRAO/WARDA), Cotonou.

Al-Hassan, R. M, Agbekornu, H. G. and Sarpong, D. B. (2008). Consumer preference for rice quality characteristics in Accra and the effects of these preferences on price. Agric. Food Sci. J. Ghana 7:575-591.

Alizadeh, M. R. and Bagheri, I. (2009). Field performance evaluation of different rice threshing methods. *International Journal of Natural and Engineering Sciences. 3(3): 1*39-143.

Anonymous (1985). International Rules for Seed Testing. *Seed Science and Technology*. 13: 299-513.

Anonymous, (2007). Albert Agriculture and Food; Using 1,000 Kernel Weight for Calculating Seeding Rate and Harvest Losses; Available on line at http//www1 .agric.gov.ad/$department/ deptdocs. nfs/all/agdex8. Accessed 12/12/2014.

Anonymous, (2008a). IITA-Bountiful Rice Harvest from 'Sawah' System. Available on- line at http//www.iita.org/cms/details/news_details.asp?articled=1615&z-neid=81. Accessed 22/09/2014.

Asante, M. D., Asante, B. O., Acheampong, G. K., Wiredu, A. N., Offei, S. K., Gracen, V., Adu-Dapaah, H. and Danquah, E. Y. (2013). Grain quality and determinants of farmers' preference for rice varietal traits in three districts of Ghana: Implications for research and policy, *Journal of Development and Agricultural Economics*, Pp: 284-286.

Association of Official Seed Analysis (AOSA) (1981). Rules for Testing Seeds. *Journel of Seed Technology*. 6: 1-25

Astegar Z. R, Sedghi M and Khomari S. (2011), "Effects of Accelerated Aging on Soybean Seed Germination Indexes at Laboratory Conditions", *Not Sci Biol.*, Vol. 3, No. 3, pp. 126-129.

Balesevic-Tubic S, Malenèiæ D, Tatiæ M and Miladinovic J (2005), "Influence of aging process on biochemical changes in sunflower seed", HELIA, Vol. 28, No. 42, pp. 107-114.

Banaszek M. M. and Siebenmorgen T. J. (1990). Head rice yield reduction rates by Moisture adsorption. Transactions of the ASAE. 33(4): 1263-1269.

Basorun, J. O., (2003). Analysis of the Relationships of Factors Affecting Rice Consumption in a Targeted Region in Ekiti-State, Nigeria. *Journal of Applied Quantitative Methods*, vol. 4, no. 2 pp. 145-153.

Basu, R. N. (1995). Seed Viability. In. Seed Quality: Basic Mechanisms and Agricultural Implications. Amarjit, S. Basra (Eds). Food Products Press. An Imprint of the Haworth Press Inc. New York, London, Norwood (Australia). Pp 1-5. (ISTA Handbook on Seedling Evaluation 3rd Edition, 2003, 8 -13).

Berisavljevic, G. K., Blench, R. M., and R. Chapman. (2003). Some Features of Rice Production in Ghana. Available online at http//www.odi.org/ resources/ downloaded/3159.pdf. Accessed 09/24/09.

Biabani A, Boggs LC, Katozi M and Sabouri H (2011), "Effects of seed deterioration and inoculation with Mesorhizobium cicerion yield and plant performance of chickpea", *Australian Jour. of Crop Science*, Vol. 5, No. 1, pp. 66-70.

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

Bourgeois, L. (1993). Vigour loss of wheat seed caused by threshing. MSc. Thesis, Department of Plant Science, University of Manitoba, WinniPeg, MB.

Chabrol, D., Chimwala, M., Cuffe, O., Favre, B., Hanyona, S., Heijmans, E., Marzin, C., Osborn, P., Sultan, J. and Tissot, C. (1996). The Technical Centre for Agricultural and Rural Cooperation. ACP-EU Lome. 6: 12-15.

Chin, H. F. (1988). Storage and Testing of Forage seeds in the Tropics. www.fao.org.AG/AGP.doc.PUBLC.pdf.

Copeland, L. O. (1976). Principles of Seed Science and Technology. Burgess Pub. Com; Minncapolis, Minnesota. pp. 164-165.

Dadalani, M., M.S. Islam, I. Ahmad and Manandhar, G.B. (2003). Seed Drying and Storage. Addressing Resource Conservation Issues in Rice-Rice Systems of South Asia A Resource Book. pp. 243-248.

Dalton, T. J. and Guei, R. G. (2003). Productivity gains from rice genetic enhancements in West Africa: countries and ecologies. *World Development*, *31*(2), 359-374.

Dhingra, O. D., Jham, G. and Napoleao, I. T. (1998). Ergosterol accumulation and oil quality changes in stored soybean. *Mycopathologia*, v.143, p.85-91.

Dilday, R. H. (1987). Influence of threshing cylinder speed and grain moisture at harvest on milling yield of rice. Proceedings of the Arkansas Academy of Science, 41, 35-37.Dilday, R. H. (1987). Influence of threshing cylinder speed and grain moisture at harvest on milling yield of rice. Proceedings of the Arkansas Academy of Science, 41, 35-37.

Divsalar, M. and Oskouie, B. (2013). *Technical Journal of Engineering and Applied Science*s.

Du, Y. and Huang, Z. (2008). Effects of seed mass and emergence time on seedling performance in Castanopsis chinensis. Forest Ecology and Management. Vol. 255(7): 2495-2501.

Dübbern, De. Souza, F. H. and Marcos-Filho, J. (2001). The Seed Coat As A Modulator Of Seed-Environment Relationships In Fabaceae. Rev. bras. Bot. vol.24 no.4 São Paulo Dec.

Duffuor, K. (2009). Budget Statement and Economic Policy of the Government of Ghana for the 2010 Fiscal Year.

Ellis, R. H. and Roberts, E. H. (1980). Improved equations for the prediction of seed longevity. *Annals of Botany* 45:13–30.

Eskandari, H. (2012) seed quality variation of crop plants during seed development and maturation. (I*nternational Journal of Agronomy and plant protection. Vol.*, 3(11), 557-560.

FAO (1981). Cereal and grain-legume seed processing. Technical Guidelines. No.21.

FAO. (2004). Rice is life. Food and Agricultural Organization of the United Nations. (Rome, Italy). 62-69.

FAO. (2007). Estimates of Postharvest Losses of Rice in South East Asia. Available online at [http://www.fao.org./News/ FACTFILE /FF9712-EHTM [Accessed 2nd May 2010]

Feiffer, A., Spengler, A., Döscher, W., Meier, W. F. and Lange, M. (2001). Fehleranalyse beim Mähdrusch. *Getreide Magazi.*, **2**: 116–119.

Food Agency Organization. (1995). Rice Post Harvest Technology, pp.167-179. Ministry of Agriculture, Forestry and Fisheries, Tokyo, Japan.

Food and Agriculture Organization (FAO) (2004). Twenty-Third Regional Conference for Africa, Johannesburg, South Africa , March 1-5, 2004. International Year of Rice.

Food and Agriculture Organization (FAO) (2008). Rice: production up by 1.8%, according to forecasts: The market is still narrow and weak trade http:// www.fao.org/NEWSROOM/fr/news/2008/1000820/index.html Accessed: 14/ 04/14.

Futakuchi, K. and Sié, M. (2009). Better exploitation of African Rice (*Oryza glaberrima* Steud.*)* in varietal development for resource-Poor Farmers in West and Central Africa. *Agricultural journal*, Vol.4, Ed.2, Pp: 96-102.

Grass, L. and Tourkmani, M. (1999). Mechanical damage assessment in rejected durum wheat seed lots in Morocco. Seed Sci. Tech., 27(3): 991-997. **.**

Hagrove, T. (1997). Jasmine85 compete with imports, The Rice World, Ed.13, http://www.agcomintl.com/jasmin.htm. Accessed: 15/01/14

Harrison, H. P. (1992). Grain separation and damage of an axial flow combine. Can. Agric. Eng. 34: 49-53.

Hayma, J. (2003). The storage of tropical agricultural products. Agrodok No. 31. Agromisa Foundation, Wageningen, Netherlands.

International Rice Research Institute (IRRI) (2005b). Wild rice taxonomy, *Crop Science*, Vol: 8, p: 10.

International Seed Testing Association (ISTA) (2003). https://www.seedtest.org/upload/cms/user/STI126Oct2003.pdf (accessed 15/01/2015).

ISTA, (2003). Handbook on Seedling Evaluation International Seed Testing Association

ISTA (2007). *International Rules for Seed Testing*. International Seed Testing Association, Bassersdorf, Switzerland.

Jahufer, M.Z.Z. and Borovoi, V.V. (1992). The effect of mechanical damage to maize (Zea mays L.) seed germination, seed morphology and subsequent grain yield. *Journal of Applied Seed Production*, 10. 67-77.

Japanese International Cooperation Agency JICA (2008). Ministry of Food and Agriculture, Republic of Ghana. The study on the promotion of domestic rice in the Republic of Ghana (Final report).

Jones, M. P., Dingkuhn, M., Aluko, G. K., and Semon, M. (1997**).** Interspecific *Oryza sativa* L. x *Oryza glaberrima* Steud. Progenies in upland rice improvement, *Euphytica*, Vol.92, Pp: 237-246.

Juliano, B. O. (1993). Rice in Human Nutrition. FAO, Rome. Available at http// www. fao.org/inpho/content/documents//vlibrary/.../T0567E00.htm. Accessed 10/05/2014.

Jyoti, and Malik, C.P. (2013). A review on seed deterioration. *International Journal of life Science Biotechnology and Pharma Research ISSN* 2250-3137 vol 2 no3,July 2013 pp. 376, 380.

Khatun, A, Kabir, G. and Bhuiyan, M.A.H. (2009), "Effect of harvesting stages on the seed quality of lentil (Lens culinaris L.) *during storage", Bangladesh Jour. Agril. Res* ., Vol. 34, No. 4, pp. 565-576.

Khazaei J., Shahbazi F. and Massah J. 2007. Evaluation and modeling of physical and physiological damage to wheat seeds under successive impact loadings: mathematical and neural networks modeling. *journal of Crop Sci.* 48(4): 1532-1544.

Khazaei, J. (2009). Influence Of Impact Velocity And Moisture Content On Mechanical Damages Of White Kidney Beans Under Loadings Cercetări Agronomice în Moldova .Vol. XLII , No. 1 (137).

Kibinza S, Vinel D, Côme D, Bailly C. and Corbineau F (2006), "Sunflower seed deterioration as related to moisture content during ageing, energy metabolism and active oxygen species scavenging", *Physiologia Plantarum,* Vol. 128, No. 3, pp. 496-506.

Krishnan P, Nagarajan S, Dadlani M. and Moharir A. V. (2003), "Characterization of wheat (*Triticum aestivum* L.) and soybean (*Glycine max* L.) seed under accelerated aging condition bye proton nuclear magnetic spectroscopy", *J Seed Sci Technol.,* Vol. 31, pp. 541-550.

Krzyzanowski F. C. 1998. Relationship between seed technology research and federal plant breeding programs. Sci. agric. Vol. 55 special issue Piracicaba. Print version ISSN 0103-9016.l.scientia@esalq.usp.br .

Kuo, P. (2009). Grain Drying Principle. Suncue company Limited. Paper presentation at the workshop on Rice Milling Revitalization in Jakarta 7-9 may 2009 DG-PMAP, Ministry of Agriculture and Bulog. Jakarta

Li, J. (2003). The Natural History of Rice: Rice. In: *Food and Culture Encyclopedia*: The Gale Group, Inc.

Linares, O. F. (2002). African Rice (*Oryza glaberrima*): History and future potential, *National Academy of science*, United States of America, Vol.99, Pp: 16360-16365.

Lyon F. and Afrikorah-Danquah. (1998). Small-scale seed provision in Ghana: Social relations, contracts and institutions for micro-enterprise development. *Ag REN, Network Paper No.84*.

Mahadevappa, M. and B. S. Nandisha, (1987). A review of the status of genetic analysis of characters important in harvest, post-harvest and seed technology of rice (Oryza sativa L) in southern India. *Seed science and Technology*. 15, 585-591.

Marshal A. H. and Levis D. N. (2004), "Influence of seed storage conditions on seedling emergence, seedling growth and dry matter production of temperate forage grasses", *J Seed Sci Technol.*, Vol. 32, pp. 493-501.

Mbora , A., Schmidt, L., Angaine, P., Meso, M., Omondi, W., Ahenda, J., Barnekov, Lilleso J. P., Mwanza, J., Mutua, W.R., Mutua, N. A. and R. Jamnadass. (2009). Tree Seed Quality Guide. Available online at http//www. worldagroforestry.org. Accessed 12/02/10.

Mcdonald, M. B. (1998). Seed quality assessment. *Seed Science Research* 8:265–275.

Miah, A. K, Roy, A. K., Hafiz, M. A., Haroon, M. and Seddique, S. S. (1994). A comparative study on the effect of rice threshing methods on grain quality. Agricultural Mechanization in Asia, Africa and Latin America,, 25(3), 63-66.

Micheal A. M. and Ojha T. P. (1989): Principles of Agricultural Engineering Vol. 1 Jain Brothers India Pp 297-307.

Ministry of Food and Agriculture, Accra, Ghana. MOFA (1999). Task force report on proposals for improving rice production and quality in Ghana, Ministry of Food and Agriculture, Accra, Ghana. Accessed on June 25 2014 at http://mofa.gov.gh/site/?

Ministry of Food and Agriculture, Accra, Ghana. MOFA (2000). Report of the Committee on improving the quality of locally produced rice to reduce imports. Ministry of Food and Agriculture, Accra, Ghana. Accessed on June 25 2014 at http://mofa.gov.gh/site/?

MOFA (Ministry of Food and Agriculture), (2011) a. Agriculture in Ghana facts and figures (2010). Accra, Ghana: Statistics Research and Information Directorate MoFA. 2012. 2012 Fertiliser and Seed Subsidy Programme Announced. Accessed on June 25 2014 at http://mofa.gov.gh/site/?p=10057

Mohammadi H, Soltani A, Sadeghipour H R and Zeinali E (2011), "Effect of seed aging on subsequent seed reserve utilization and seedling growth in soybean", Inter. *Jour. Of Plant Production*, Vol. 5, No. 1, pp. 65-70.

Msuya D. G. and Stefano J. (2010). Responses of Maize (Zea Mays) seed germination capacity and vigour to selection based on size of cob and selective threshing. *World Journal of Agricultural Science*, 6: 683-688.

Muliokela S. W. (1995) Zambia Seed Technology Handbook. Seed control and certification Institute, Chilanga, Zambia. pp. 70-146

Nguyen C. N, and Kunze O. R. (1984). Fissures related to post-drying treatments in rough rice. Cereal Chemistry. 6(1): 63-68.

Nguyen, V. N. (2001). Rice Production, Consumption and Nutrition. FAO, Rome.

Nkama, I. (1992). Local Rice Processing. Paper presented at the monthly Technology Review Meeting for Taraba ADP, Adamawa, Nigeria.

Nogueira1, F. C. B., Pinheiro C. L., Filho S. M., Maria da Silva Matos D., (2014). Seed germination and seedling development of *Anadenanthera colubrina* in response to weight and temperature conditions. *Journal of Plant Sciences* 2(1): 37-42

Nwanze K. F, Mohapatra S, Kormawa P, Keya S, Bruce-Oliver S (2006). Rice development in sub-Saharan Africa. *J. Sci. Food Agric*. 86:675-677

Parker W.C., Noland, T. L. and Morneault, A.E. (2006). The effects of seed mass on germination, seedling emergence, and early seedling growth of eastern White pine (Pinus strobes L.). Forests. Vol.32 (1): 33-49.

Policarpio, J. S. and Mannamy, J. A. (1978). The development of the IRRI portable thresher, a product of rational planning, pp 56-65. AMA Spring.

Ponican, J., Angelovic, M., Jech, J., Žitnák, M., Galambošová, J. and Findura, P. (2009). The Effect of the Design Concept of Combine Harvester Threshing Mechanism on the Maize Crop Threshing Quality. *Savremena poljoprivredna tehnika*, **35(4)**: 268-274.

Ragasa, C., Dankyi, A., Acheampong, P., Wiredu, A. N., Chapoto, A., Asamoah, M., & Tripp, R. (2013). Patterns of adoption of improved rice technologies in

Ghana. *International Food Policy Research Institute Working Paper*, *35* Pp 6-8.

Rahman M.M, Hampton J.G, Hill M.J. 2004. Effect of seed moisture content following hand harvest and machine threshing on seed quality of cool tolerant soybean. Seed Science and technology. 32(10): 149-158.

Reddy, B.S. and Charkraverty, A. (2004) Physical properties of raw rice and parboiled paddy. Biosystems Eng. 88(4): 461 – 466.

Ribeiro C. A. D, Costa M. P., Senna D. S. and Caliman J. P. (2012). Fatores que afetam a germinacao das sementes e a biomassa de plantulas de Tabebuia heptaphylla. Floresta. Vol. 42(1): 161-168.

Rickman, J. F., Bell, M. and Shires, D. (2006). Seed Quality, Available at http// www.knowledgebank.irri.org. Accessed 21/12/2014.

Ruiz de Clavijo, E. (2002). Role of Within-individual Variation in Capitulum Size and Achene Mass in the Adaptation of the Annual Centaurea eriophora to Varying Water Supply in a Mediterranean Environment. Annals of Botany. Vol.90: 279-286.

Salari, K., Amiri Chayjan, R., Khazaei, J. and Amiri Parian, J. (2013). Optimization of independent parameters for chickpea threshing using response surface method (RSM). *Journal of Agricultural Science and Technology*, *15*(3), 467-477.

Santos, B.M. (2007). *Seed Quality and Seed Technology*. IFAS Extension, University of Florida. Pp. 19 - 21.

Sarla, N. and Mallikarjuna, S. B. P. (2005). *Oryza glaberrima*: A source for improvement of *Oryza sativa*, *Current science*, India, Vol.86, Ed.6, Pp: 955-963.

Saxena, J.B. Sirohi, B.S. and Sharma, A.K. (1971). Power requirements of Ludhiana type threshers. *J. Agric. Engin*. 8: 35-43.

Seed Testing and Seed Quality Control in Asia (STSQCA), (2007). J. Agr. Sci. Tech. (2013) Vol. 15: 467-477

Seed Testing Principles and Procedures (STPP). (2014). http://seednet.ap.nic. in/ Stl/htmlpages/GerminationTesting.htm (accessed 15/11/2014).

Shabbir, M. A., Anjum, F. M., Zahoor, T. and H. Nawaz. (2008). Mineral and Pasting Characterization of Indica Rice Varieties with Different Milling Fractions. *International Journal of Agriculture and Biology*. Vol. 10: pp 556-560.

Sheidaei. S, Abad. H. H. S, Hamidi. A, Mohammadi.G. N. and Moghaddam. A. (2014). Relationship between laboratory indices of soya bean vigour with field emergence and yield Pp 282.

Shelar V. R., Shaikh R. S. and Nikam A. S. (2008), "Soybean seed quality during storage: A review", *Agric. Rev.,* Vol. 29, No. 2, pp. 125-131. International Journal of life Science Biotechnology and Pharma Research ISSN 2250-3137 vol 2 no3,July 2013

Siebenmorgen, T.J, Perdon, A. A., Chen, X.and Mauromous, A. (1998). Relating rice milling quality changes during adsorption to individual kernel moisture content distribution. Cereal Chem. 75(1): 129-136.

Simic, B., Popoviæ, R., Sudaric, A., Rozman, V., Kalinovic, I. and Cosic, J. (2007), "Influence of Storage Condition on Seed Oil Content of Maize, Soybean and Sunflower", *Agriculturae Conspectus Scientificus,* Vol. 72, No. 3, pp. 211-213.

Smith, B. D. (1998). The Emergence of Agriculture, Scientific American Library, Diane Publishing Company, New York, P: 2.

Somado, E.A., Guei, R.G. and Keya, S. O. (Ed) (2008). "*NERICA: The New Rice for Africa a Compendium*". Available at http//www.warda.org/publications/nerica -comp/Nerica%20Compedium.pdf. Accessed 18/12/2014.

Sorensen, F. C. and Campbell, R. K. (1993). Seed weight-seedling size correlation in coastal Douglas-fir: genetic and environmental components. *Canadian Journal of Forest Research*, *23*(2), 275-285.

Sosnowski, S. and Kuzniar, P. (1999). Effect of Dynamic Loading on the Quality of Soybean. Department of Agricultural Product. Int. Agrophysics. 13: 125-132.

Spokas, L., Steponavicius, D. and Petkevicius, S. (2008). Impact of Technological Parameters of Threshing Apparatus on Grain Damage. *Agronomy Res.*, **6**: 367–376.

Srivastava, A. K., Goering, C. E. and Rohrabach, R.P. (1998). Engineering principles of agricultural machines. ASAE-TextBook Number 6. Published by American Society of Agricultural Engineers. Pamela Devore-Hansen, Editor Books & Journal, USA.

St Clair, J. B., and Adams, W. T. (1991). Effects of seed weight and rate of emergence on early growth of open-pollinated Douglas-fir families. *Forest Science*, *37*(4), 987-997.

Staple Crop Programme, (2011). Global Food Security Response, Initial Training Manual for Improve Rice Post Harvest Technology in West Africa pp.21

Takoradi, A. A. (2008). Ghana needs 700,000 metric tonnes of rice annually but currently produces only 150,000. Available at http//www.modernghana. com/

news/185343/1/ghana-needs-700000-tonnes-of-rice-annually-but-cur.htm.
Accessed 12/09/2014.

Tanasugarn, L. (1998). Jasmine rice crisis: A Thai perspective, *Biological Diversity and Biotechnology*, Thailand, Vol.1, Pp: 1-64..

van-Gastel, A.J.G. Pagnotta, M. A. and Porceddu, E. (Eds.). (1996). Seed Science and Technology. Proceedings of a Train-the-Trainers Workshop sponsored by Med-campus Programme (EEC), 24 April to 9 May 1993, Amman, Jordan. ICARDA, Aleppo, Syria. vii+311 pp.

Vaughan, D. A., Morishima, H. and Kadowaki, K. (2003). Diversity in the *Oryza* genus. *Current Opinion in Plant Biology*, Vol.6, Pp: 139-146.

Vearasilpa S., Somchai P., Nattasak K., Sa-nguansak Th., Sangtiwa S., Elke P. 2001. Assessment of Post Harvest Soybean Seed Quality Loss. Conference on International Agricultural Research for Development, Institute for Agricultural Chemistry, Georg-August University, Göttingen, 37075 Germany.

WARDA, (2004). The Rice Challenge in Africa. http//www.warda.org. (accessed 15/01/2015)

West Africa Rice Development Association (WARDA) (1996). Annual Report, Pp: 7-17. http://www.warda.cgiar.org/publications/wardar96.pdf.

Wimberly, J. E. (1983). Technical Rice Hand book for the Paddy rice Postharvest Industry in Developing Countries International Rice Research Institute, Los Banos, Philippines. [www.fao.org/docrept/1838E10htm][Accessed 14th April 2010]

APPENDICE

Appendix 1: Analysis of Variance Table for Moisture content

Source	DF	SS	MS	F	P
Rep	2	0.26741	0.13370		
Var	2	6.60074	3.30037	76.24	0.0000
T M	2	0.12519	0.06259	1.45	0.2647
Var*T M	4	0.21481	0.05370	1.24	0.3333
Error	16	0.69259	0.04329		
Total	26	7.90074			

Grand Mean 10.719 CV 1.94

Appendix 2: Analysis of Variance Table for percent seed germination

Source	DF	SS	MS	F	P
Rep	2	8.22	4.111		
Var	2	12.67	6.333	0.30	0.7436
T M	2	172.67	86.333	4.11	0.0362
Var*T M	4	1078.67	269.667	12.85	0.0001
Error	16	335.78	20.986		
Total	26	1608.00			

Grand Mean 79.000 CV 5.80

Appendix 3: Analysis of Variance Table for Seed conductivity

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.734	0.3670		
Var	2	3.983	1.9915	0.65	0.5358
T M	2	39.130	19.5650	6.38	0.0092
Var*T M	4	154.984	38.7459	12.63	0.0001
Error	16	49.094	3.0684		
Total	26	247.924			

Grand Mean 5.6541   CV 30.98

Appendix 4: Analysis of Variance Table for 1000 seed weight

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.01336	0.00668		
Var	2	1.16056	0.58028	68.15	0.0000
T M	2	0.66809	0.33404	39.23	0.0000
Var*T M	4	6.34862	1.58716	186.39	0.0000
Error	16	0.13624	0.00852		
Total	26	8.32687			

Grand Mean 26.961   CV 0.34

Note- Var means variety and T M means threshing method

Appendix 5: Analysis of Variance Table for Broken Seeds

Source	DF	SS	MS	F	P
REP	2	1.12667	0.56333		
THRESH	2	1.26889	0.63444	25.81	0.0000
VARIETIES	2	0.01556	0.00778	0.32	0.7332
THRESH*VARIETIES	4	0.11556	0.02889	1.18	0.3588
Error	16	0.39333	0.02458		
Total	26	2.92000			

Grand Mean 0.6667   CV 23.52

Appendix 6: Analysis of Variance Table for Moisture content

Source	DF	SS	MS	F	P
Rep	2	0.08296	0.04148		
Var	2	5.06074	2.53037	36.03	0.0000
T M	2	0.55630	0.27815	3.96	0.0401
Var*T M	4	0.03926	0.00981	0.14	0.9650
Error	16	1.12370	0.07023		
Total	26	6.86296			

Grand Mean 10.963   CV 2.42

Appendix 7: Analysis of Variance Table for Seed conductivity

Source	DF	SS	MS	F	P
Rep	2	2.3207	1.16036		
Var	2	17.6529	8.82646	14.00	0.0003
T M	2	7.2670	3.63351	5.76	0.0130
Var*T M	4	7.3349	1.83371	2.91	0.0552
Error	16	10.0874	0.63046		
Total	26	44.6629			

Grand Mean 7.3778 CV 10.76

Appendix 8: Analysis of Variance Table for percent seed germination After storage

Source	DF	SS	MS	F	P
Rep	2	6.116	3.058		
Var	2	46.519	23.259	1.55	0.2434
T M	2	6.421	3.211	0.21	0.8101
Var*T M	4	476.731	119.183	7.92	0.0010
Error	16	240.759	15.047		
Total	26	776.546			

Grand Mean 83.370 CV 4.65

Appendix 9: Analysis of Variance Table for seedling vigour index

Source	DF	SS	MS	F	P
Rep	2	5476	2738		
Var	2	289395	144698	5.99	0.0114
T M	2	149702	74851	3.10	0.0728
Var*T M	4	42720	10680	0.44	0.7763
Error	16	386333	24146		
Total	26	873625			

Grand Mean 2348.8   CV 6.62

Appendix 10: Analysis of Variance Table for 1000 seed weight

Source	DF	SS	MS	F	P
Rep	2	1.8253	0.91266		
Var	2	1.0551	0.52757	3.77	0.0457
T M	2	0.6417	0.32087	2.29	0.1334
Var*T M	4	9.9785	2.49463	17.81	0.0000
Error	16	2.2412	0.14008		
Total	26	15.7420			

Grand Mean 27.558   CV 1.36