DECLARATION

"I certify that all the work contained in this dissertation is my own except references made to other people's work which has been duly acknowledged, and that this research has not been submitted before for any degree in any university or college".

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DEDICATION

"This thesis is dedicated to my beloved parents, Mr. and Mrs. Akai (the former of blessed memory) and my wife Mrs Juliana Akai and kids Crispin W. Akai, Christian B. Akai and Jessica Y. Akai.

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The successful completion of this thesis would not have been possible without the mercy of the Almighty God. I therefore give thanks to Him for giving me sustained strength through out the period of this work. May blessed be His name forever!

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ABSTRACT

An experiment was conducted at the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, between March and October 2007. The principal aim of the experiment was to evaluate the quality of *Jatropha curcas* seed and its seedling establishment in pot in the field. The seed were subjected to two storage conditions; the ambient room storage (24-35^{o}C, 72-96% RH) and cold storage (10-15^{o}C, 90% RH). Data collected on seed quality aspects were: number of seeds per fruit, seed kernel to shell ratio, thousand seed weight, germination percentage, seedling dry weight, fungi associated with the seed and seed oil content. Seedling growth parameters studied were: plant height, stem diameter, petiole length, internode length, number of leaves, and number of leaf buds, leaf area, canopy spread and number of branches. Seed oil content, fungi identification and seedling growth parameters were determined both at the beginning and at the end of the six months storage period. The results revealed that *J. curcas* pod contains three seeds (2.99 -3). It was observed that seeds from the Forest Zone were better in seed oil content (36%-53%), seed weight (701g), seed vigour index (5-7) and seedling performance than seed collected from the other two zones. Also, it was found out that cold storage conditions preserved the seeds of *J. curcas* better than room storage conditions but tended to promote fungi survival. The results further showed that seedlings of *J. curcas* could easily be raised irrespective of the zone of seed collection. Though seedlings parameters measured e.g. plant height (18-20cm vs 13– 16cm), petiole length (6-7cm vs 5-6cm) etc. after seed drying appear superior over those after seed storage in absolute terms, *Jatropha curcas* seedlings could easily be raised during both major and minor seasons. From the experiment, seeds of *J. curcas* are storable for at least six months without any appreciable loss of viability provided that the seeds moisture is reduced to 10% or below and placed in sealed moisture proof containers. For better oil conservation,

the result suggests that *Jatropha curcas* seeds should be stored under ambient room conditions whereas germination is better preserved under cold store seed storage conditions.

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CHAPTER ONE

1.0 INTRODUCTION

Jatropha curcas is commonly called physic nut, purging nut, barbados nut, pig nut or fig nut (Henning, 2003; Benge, 2006). The plant derives its name from two Greek words jatrós (doctor) and trophé (food) which connote medicinal uses (Henning, 2004).Taxonomists classified *Jatropha* as the genus but most literature simply refer to the plant as Jatropha, adding it to the list of common names.

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Physic nut belongs to the tribe *Joannesieae* of *Crotonoideae* in the family *Euphorbiaceae* (L.) with 170 known species. It is a dicotyledonous deciduous small perennial tree/shrub that grows up to the height of 5m (Francis *et al*., 2005). The greenish white flowers of *Jatropha* are usually monoecious but occasionally hermaphroditic ones develop. The complex inflorescence borne terminally has main and co-inflorescences with paracladia that is botanically described as a cyme (Heller, 1996).

Like most members of its family, Jatropha is pollinated by insects and its fruit initiation, development and maturation take nine weeks. The resultant trilocular ellipsoidal fleshy fruit has green exocarp with three seeds which turns yellow on maturity. The seed black in colour, averagely measures 18 mm long, 10 mm wide and has a thousand seed weight of about 727g (Henning, 2004; Benge, 2006).

Some authorities dispute the origin of *J.curcas*, but many authors have reported that the plant is native to Mexico and Central America but was spread to Africa and Asia by Portuguese seafarers where it is now widely cultivated (Dokosi, 1998; Ginwal *et al*., 2004; Henning, 2004; Francis *et al.*, 2005). Described as ‘pantropic’ Jatropha plant has successfully

been introduced into many tropical areas as it is found growing in Australia, India, Brazil, Fiji, Honduras, Panama, El Salvador, Jamaica, Puerto Rico and parts of the Caribbean and Africa (Raju and Ezradanam, 2002; Henning, 2003)). It survives under tropical conditions requiring a temperature range of 20 - 30 °C, 300 -1200 mm rainfall per annum and an altitude of 0 – 500 m above mean sea level.

Jatropha is an important commodity for the numerous benefits one can derive from it. For instance, the seed oil is used extensively in the industry. In the 1990's, Jatropha seed was produced on large scale in Cape Verde and exported to Lisbon and Marseille for oil extraction and soap or cosmetic manufacture (Heller, 1996). The author further stated that in Mali women extract and use the seed oil for soap making and household energy.

In the agricultural sector, Jatropha could offer employ for people involve in its production, processing and marketing. According to Francis *et al*. (2005) the cultivation of the plant in India could offer employment to 5 million people all year round. In Ghana, 72% of the population in agriculture could benefit from Jatropha cultivation (Ocran, 2003). Hitherto, the plant has been cultivated for it aesthetic value as a hedge (Dokosi, 1998) but now some rural communities use the seed oil for lighting kerosene lamps or used to power generator operated mills. Meanwhile, a derived benefit is proposed by environmentalists who believe that the cultivation of Jatropha could contribute to the fight against global-warming (Heller, 1996).

It was predicted that at least 800,000 ha land will be put to oil crop production in the European countries alone by 2000 and that the introduction of specifications for biodiesel and its environmental friendliness would further generate interest in oil crops production. In Ghana, commercial Jatropha cultivation is recent and on-going projects as at 2003 have

already devoted 1,200 ha to its production (Ghana Energy Commission, 2005). The report further stated that plantations exist in farming towns located in Brong-Ahafo, Ashanti, Eastern, Volta and Greater Accra regions with mainly Non-Governmental Organizations (NGOs) operating in Northern Ghana. Meanwhile, Jatropha yield reports world-wide vary widely ranging between 0.5 ha^{-1} to 5 t ha^{-1} seed (Heller, 1996). Yields figures in Ghana are comparable if not higher, being estimated to range between 4 t ha^{-1}–5 t ha^{-1} (Ghana Energy Commission, 2005).

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Again, the complete exploitation of Jatropha could benefit crop production, in that, the seed cake after the oil extraction is an excellent source of organic manure comparable to poultry and dung manures. Heller (1996) reported that manure from *Jatropha* seed cake increased pearl millet yield more than mineral fertilizer while yield of rice in Nepal was increased by 11%. It is also reported that extracts from all parts of the plant has both medicinal and pesticidal properties (Heller, 1996; Makkar *et al.*,, 2007).

Recently, the call for energy conservation and search for alternative sources have become significant in the wake of the world energy crisis. Also, since the 1970's oil crisis coupled with the limited world oil resources, most crude oil importing countries (including Ghana) are highly motivated to develop alternative sources of energy from natural resources to meet their domestic needs, and *Jatropha curcas* has been found to be very promising (Ginwal *et al*., 2005; Oladimeji, 2007). At the national energy consumption level and its impact on the gross domestic product (GDP), Jatropha cultivation in Ghana could reduce the import bills on crude oil. Ghana Energy Commission 2005 report indicates that fuel import bill of Ghana stood at US $516.8 million and US $816.1 million in 2001 and 2004 respectively, and had hit US $ 1.3 billion in 2007.

Despite these numerous benefits and potentials, the production of Jatropha in Ghana has been faced with a number of challenges. Paramount among these set-backs includes the non-availability of high quality seed for farmers. This is substantiated by the fact that little information is available on quality seed production and postharvest handling. This affirms the report by the Adventist Development and Relief Agency (ADRA) that farmers in Ghana failed to establish Jatropha plantations due to poor quality seed emanating from poor postharvest handling including storage (ADRA, 2004).

The present study was therefore undertaken with the general objective of assessing the seed quality and seedling performance of the physic nut under different storage environments.

The specific objectives were to:

I. Determine the germination, vigour, health, seedling performance of the physic nut seed under two different storage environments

II. Assess the storability and oil content of the seed under two storage environments

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 METHODS OF SEED STORAGE

Seed is stored with the express objective of maintaining quality for both consumption and planting purposes (FAO, 1981; George, 1985; Agrawal, 1995). Chin (1988) proposed that pertinent questions concerning the principal aims of storage, quantity to store and length of storage must diligently be considered before embarking on any seed storage programme. Hong and Ellis (1996) reported that seed storage is an age old practice that started with the inception of agriculture when humans began to domesticate plants.

Reviewing methods of storage, the University of Greenwich (1999) recognised three types: traditional, improved traditional and modern types. With particular reference to West Africa, the author reported that cribs, baskets, metal tanks, mud silos, underground pits and jute /cotton bags are common methods of storage. Choice of the method to use for storing seed depends on the kind of seed (FAO, 1981). According to Tanaka (1984), tree seeds may be stored wet or dry in closed containers or by regulating the humidity of the storage area. The author cited plastic bottles, polythene bags, fiberdrums, rigid drums lined with polythene or metal drums as frequently used containers. George (1985) and UNIFEM (1994) acknowledged the availability of a wide variety of storage techniques but concluded that the choice of the technique to use depends on the quantity of seed to store, local construction materials and the climate.

According to the University of Greenwich (1999) in modern times, storage may be indoor or outdoor and stored in bulk, in silos, in bags, underground or above ground. George (1985) reported that seeds may also be successfully stored in silos when the moisture content is

maintained at between 2–3% or in moisture proof containers. On the market in recent times storage facilities range from small freezers, miniature aluminium foiled tins, bottles, glasses or plastics, metal containers, jute and cotton bags, to huge cold rooms controlled by robots (Chin, 1988).It was observed that, an air-conditioned room maintained at 20°C is conducive to store seeds for a season once the seed is packed in water-proof containers (Chin, 1988).

It is contested that some storage structures do not preserve seed quality. According to Singh (1990) in Africa and China traditional storage structures used in storing maize, rice, wheat, millet and chickpea include; mud, dung, bamboo, and rice straw silos. The author observed that high humidity and poor storage practices associated with these kinds of storage facilities provided congenial environment for microbial attack; the dominant species being *Aspergillus* spp. and *Penicillium* spp. In advanced agriculture on the other hand, controlled systems that manipulate temperature and humidity (or modified control storage) are prominent in seed storage (Cantliffe, 1998). This can be hermetically sealed containers such as tin foil packets or cans, plastic containers or temperature and humidity controlled rooms (Cantliffe, 1998). Olakojo *et al.* (2007) observed that cowpea seed in plastic bags stored better than when put in tin and earthen containers under the same conditions and contended that nylon bags should not be used in order to avoid complete damage of the seeds.

2.1.1 AMBIENT SEED STORAGE

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

(1990) reported that Japanese brown rice attained equilibrium moisture content with the environment when stored under ambient conditions.

However, storage under ambient conditions have been observed to affect seed quality in general and germination in particular. Basu (1990, 1995) indicated that serious losses of viability have been reported from areas (experiencing low relative humidity and temperature) believed to have suitable or conducive climate for the production and storage of seed. Agrawal (1995) also indicated that infestation of legume seeds by bruchids in unprotected ambient storage facilities resulted in complete loss of viability within 2-4 months of storage. Chin (1988) observed that barley seed with hulls retained viability under ambient storage conditions better than seeds of the same harvest that have been threshed. In general, storage for long or short term is improved under ambient humidity if the seed is well packaged (McCormack, 2004).

2.1.2 MODIFIED SEED STORAGE

Modified storage or controlled atmosphere storage have been harnessed to achieve long term storage. According to Lu Quanyu (1984), controlled atmosphere techniques have been adopted as main method of grain storage in China because of their efficiency in preserving grain quality. Chin (1988), reported that the latest form of modified storage in practice is cryogenic preservation mainly used for preserving genetic resources and is carried out at -196°C. Again, Hong and Ellis (1996) also emphasized that sub-zero temperatures such as -10 to -20°C are best for long term storage often required in genebanks for genetic preservation. The authors further observed that hermetic storage in nitrogen-filled package is one of the excellent means of preserving the quality of paddy rice in terms of its germination, but highly dependent on moisture content of the seed.

2.2 THE CONCEPT OF SEED QUALITY

The capacity to germinate and grow satisfactorily into a normal plant is probably the most important quality parameter desired of the seed. In practical agriculture, an all inclusive definition has it that, seed is any plant part used to regenerate the next generation of the crop (Gardner *et al*., 1985). Botanically, seed is a ripe fertilized ovule that provides an important means of reproduction, dispersal and serves as nutrition to seed-eating animals and fungi colonies (Wicklow, 1995). The term seed quality has been viewed in terms of analytical purity, genetic purity and physical purity that have gained maximum interest from seed scientists (Fraczek *et al.*, 2005).

Seed quality is often interpreted in terms of genetic traits, germination capacity, analytical purity, physical purity and storage potential (ISTA, 1986). Quality can be assessed by a range of standardized tests performed on samples taken from the seed lot; and then concluded that, the reliability of the inferences made about the quality of the seed lot depends primarily on the accuracy with which the sample represents the lot and the precision with which the laboratory tests are performed (ISTA, 1986). Simic *et al*. (2007) also viewed seed quality as a multiple criterion that encompasses several important seed attributes: genetic and chemical composition, physical condition, germination and vigour, seed size, seed moisture content, physical appearance as well as the presence of seed-borne pathogens or weed and crop contaminants.

2.2.1 SEED QUALITY ASSESSMENT

The most frequently tested seed quality parameters according to ISTA rules and standards are: physical purity, germination percentage, analytical purity, vigour, and seed health. Among these parameters, seed health testing currently suffers limited application, but

germination potential is perhaps the most important quality parameter which is often used to determine sowing rates, time of sowing or whether the seed can be stored (Tanaka, 1984; Basu, 1995). Mathur and Kongsdal (2003) contended that sowing of high quality seed is essential for improving crop yields and increasing food production. Thus, assessing seed quality before planting is most important for famers (Mathur and Kongsdal, 2003).

2.2.1.1 SEED GERMINATION

According to Gardner *et al*. (1985) and Hadidi (1996) germination is the resumption of active growth of the embryo initiated when the seed is subjected to favourable environmental conditions of moisture, temperature and oxygen. Some authorities defined germination as the emergence and development of the seedling to a stage where aspects of its essential structures indicate whether or not it is able to develop further into a satisfactory plant under favourable conditions in soil (Madsen, 1988; Copeland and McDonald, 1995; Mathur *et al.,* 2003; ISTA, 1993, 2007). Tanaka (1984) observed that germination conducted in a nursery bed is usually slower and less complete than laboratory germination and stated that the three major methods by which germination is expressed are: (1) mathematical values based on standard laboratory test results (2) germination under stressful condition and (3) biochemical testing. Basu (1990) reported that it is difficult to maintain germination capacity or the potential viability of seed especially in hot climates and acknowledged that germination results remain the prerequisite for assessing seed for planting or industrial purposes.

According to Opeke (1982), mechanical or internal physiological barriers may prevent seed germination due to imposed dormancy. Madsen (1988), defined dormancy as the state in which seeds will not germinate despite favourable external conditions which may be due to endogenous or exogenous factors. Nonetheless, Wicklow (1995) observed that seed

dormancy is a natural phenomenon that makes seeds survive storage and local extinction. However, lack of dormancy in cacao and citrus makes them exhibit vivipary and tend to make them sensitive to as they lose viability with long storage (Opeke, 1982).

2.2.1.2 TYPES OF GERMINATION

According to ISTA (1979) and Hadidi (1996) two types of germination; epigeal (exhibited by most dicotyledons) and hypogeal germination (exhibited by most monocotyledons) occur among horticultural crops and woody plants. Gardner *et al* (1985) also documented the two types of germination and explained that in hypogeal type of germination the cotyledons remain under the soil but are pushed out in the case of epigeal type of germination as the epicotyl and hypocotyl elongate. Schmidt (2000) subscribed to the epigeal and hypogeal types of germination and concluded that epigeal germination is by far the most common in woody plants. The author further recognized two intermediate types; the semi-hypogeal type in which the hypocotyl does not elongate but the cotyledons emerge and the durian type in which the hypocotyl elongates but the cotyledons do not emerge.

2.3 FACTORS INFLUENCING GERMINATION

There are several biotic or abiotic factors that influence seed germination. These factors include temperature, humidity, seed moisture, fungi pathogens, storage conditions and seed oil content among others. Copeland and McDonald (1995) documented that temperature, water, oxygen and light are important external conditions necessary for seed germination.

2.3.1 INFLUENCE OF TEMPERATURE ON GERMINATION

Gardner *et al*. (1985) reported that temperature is required for germination of non-dormant seeds. Madsen (1988), Copeland and McDonald (1995) also reported that temperature as well as water, oxygen and light are important external conditions necessary for seed germination. On the other hand, Driscoll (1990) observed that high temperatures during seed maturation may induce dormancy in seed. Some seeds require vernalization (low temperature treatment) before they can germinate, grow and initiate flowers. Driscoll (1990) observed this when he reported that winter wheat seed requires 2 °C treatment for six weeks before planting to induce flowering. On the contrary, Gardner *et al*. (1985) Copeland and McDonald (1995) stated that most tropical seeds are very sensitive to chilling during germination especially at temperatures below 10 °C. Simic *et al*. (2007) also reported that the combined effect of high temperature and relative humidity accelerate seed deterioration independent of the initial seed quality.

2.3.2 EFFECT OF SEED MOISTURE CONTENT ON GERMIATION

High seed moisture is reported to affects seed quality. Between 40%- 60% moisture content, metabolic activities increase and seed germination is triggered off resulting in the death of the embryo. An earlier report indicated that seed with hard seed coat prevented oxygen and moisture entry into seed and prevented autoxidation of linoleic and linolenic acids which are responsible for degradation of cellular organelles (Cantliffe, 1998).

2.3.3 INFLUENCE OF STORAGE ON SEED GERMINATION

Storage under high relative humidity and temperature (85% and 30 ^{o}C) was observed to promote *Aspergillus* spp growth that resulted in the loss of germination in seed within six months (Neergaard, 1979). ADRA- Ghana (2004) documented that poor storage coupled with

diseases resulted in the loss of germination in *Jatropha curcas* seed. Ginwal *et al* (2004) also reported that germination of *Jatropha curcas* seed fell below 50% within 15 months of storage. However, the low germination in freshly harvested seeds of *Jatropha curcas* may be due to dormancy. In a storage experiment, seed infected by *Aspergillus* spp. (A. *flavus*, A. *candidus* and A. *rubber*), lost germination capacity within six months when stored at 85% humidity and 30 ^{o}C but uninfected seed maintained a germination percentage of 95 (Neergaard, 1979).

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2.3.4 EFFECT OF FUNGI PATHOGENS ON SEED GERMINATION

FAO (1981) reported that disease pathogens are sometimes responsible for the loss of germination in seeds. Wicklow (1995) similarly reported that under commercial grain storage, fungi are the primary cause of seed deterioration which is depicted by loss of germinability, decrease in dry matter, increase fat acidity, grain heating, and ultimate sprouting. Wu and Cheng (1990) also reported that seed-borne pathogens are major factors which reduce seed vigour and listed *Curvularia lunata, Drechslera maydis* and *Fusarium moniliforme* as the most prominent ones attacking sorghum seed. Mathur *et al.* (2003) also reported that seed-borne fungi that are capable of producing symptoms on young seedlings or even cause death are species of *Alternaria, Ascochyta, Fusarium, Bipolaris, colletotrichum, Macrophomina and Pyricularia.* Neergaard (1979) found that many of the seed-borne fungi associated with cowpeas reduced seed germination and produced symptoms on infected seedlings. Also, black stem caused by *Phoma medicaginis* could kill young seedlings soon after germination, but loose smuts of cereals may remain latent and show only when the plant matured, resulting in low seed vigour (Maloy, 1993).

2.3.5 EFFECT OF SEED OIL ON GERMINATION

Deterioration of stored grain containing fats or oils may be accompanied by an increase in fatty acids, measured in terms of fatty acid value (FAV), which make partially spoiled fats rancid and is caused by mould determined by favourable moisture conditions (Neergaard, 1979). Due to its high oil content, Ginwal *et al*., (2004) reported that jatropha seeds do not store for long and that germination fell below 50% in 15 months of storage. The oil content of seeds can affect seed storage life and consequently germination. Bankole *et al.* (2005) submitted that melon seed is difficult to store because germination and vigour deteriorate quickly in storage due to the high oil content in the seed. Similar observations made by Simic *et al*. (2007) indicated that seed longevity is affected by seed oil content due to noticeable decrease and deterioration in stored seed oil content and thus affected seed quality particularly germination.

2.2.1.3 SEED VIGOUR

Assessment of the ability of seed to germinate is a common test for seed quality. Vigour is not a simple measurable property, but rather a qualitative character controlled by several factors that affect the germinating seeds (Hampton and Coolbear, 1990). Seed vigour can be defined as the sum total of those properties which determine the potential level of activity and performance of the seed lot during germination and seedling performance (Matthews and Powell, 1995). Cantliffe (1998) also defined vigour as the ability of the seed to germinate rapidly and produce normal seedling under a wide range of conditions. Due to variations in vigour, seed lots with similar germination may respond differently when subjected to adverse field conditions. Matthews and Powell (1995) also reported that vigour differs among many species due to ageing and accumulation of degenerative changes that culminate in death or failure of the seed to germinate.

Vigour can be affected by mechanical damage to the seed coat or embryo, stage of maturity at harvest, seed size, senescence, attack by pathogens and drying temperature (Bishaw and van Gastel, 1993). Also, Tomer and Maguire (1990) observed that low vigour may be due to genetic, physiological, cytological, mechanical and microbial factors. Seed quality also relate to field emergence. It is required that seed germinates after storage and produce vigorous plants in a wide range of field conditions, a trait that is strongly related to seed vigour (Madsen, 1988; Egli and Bluening, 2007).

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2.2.1.4 SEED HEALTH

ISTA (1979) stated that seed health is an important factor in the control of crop diseases and further observed that infected seed is less viable, has low germination, reduced vigour and reduced yield. Okra, tomato, hot pepper, maize, wheat and cowpea seeds severely infected with diseases and pests failed to germinate or produced high percentage abnormal seedlings (ISTA, 1979). Seed health testing in recent times, has become an integral part of seed quality assessment. According to ISTA (1993, 2007), the health of seed refers primarily to the presence or absence of disease-causing organisms, such as fungi, bacteria, and viruses, and animal pests such as eelworms and insects, but physiological conditions such as trace element deficiency may be involved.

Diekman (1996) reported that any part of the plant is subject to disease, which may occur at any stage: seed, seedling, growing plants etc. To emphasize, FAO (1981) gave a list of fungi associated with seeds which may cause disease as *Aspergillus spp., Botyrodiplodia theobromae, Cladosporium spp., Curvularia pennisetium, Dreschlera maydis, D. oryzae, D. setariae, Fusarium spp., Pennicillium spp., Phoma exigua, and Trichoconiella padkii.* However, Agarwal (1995) reported that seedborne microflora association with seed does not

necessarily result in disease condition but may rather enhance seed protection. The author further observed that *Oryzopsis maleacea* seed dormancy was broken by the invasion of *Penicillium funiculasum* on the seed palea and lemma and thus improved germination.

The methods of identifying seeds-associated fungi have been reviewed by many scientists and these include: inspection of dry seed, washing test, blotter method, embryo count, seedling symptom test, agar plate method, and polymerase chain reaction among others. (Neergaard, 1979; Mathur and Kongsdal 2003; Mathur *et al*., 2003). Maude, (1988) reported that seed high in purity and germination but infected with seed-borne pathogens is of low planting value. Jindal and Thind (1990) also reported that *Pennicillium acidovorans* and *Fusarium semitectum* were found to be associated with shrivelled seeds of cowpea. In addition, Heller (1996) reported that *Phytopthora spp., Pythium spp., Fusarium spp.* and *Helminthosporium tetramera* are some of the fungi found associated with *Jatropha curcas*.

Effects of seed-borne pathogens on plant health vary widely. Some pathogens such as *Gloeotinia temulata*, which cause blind seed in fescue, kill the seeds as they develop. Others such as *Phoma medicaginis*, the causal agent of spring black stem in alfalfa has great propensity to kill the seedling (Maloy, 1993). Neergaard (1979) also pointed out that seed can serve as a vehicle for the dissemination of plant pathogens when they bear inoculum, which can result in disease outbreak through infection in the endosperm or embryo.

2.3 FACTORS AFFECTING SEED QUALITY

Many workers have reviewed the inherent ability of a seed to be stored for long or short term, and based on that divided seed into two broad categories viz: orthodox and recalcitrant seeds (Berjak *et al*., 1990; Hong and Ellis, 1996; Sivritepe, 1998; Fenner and Thompson, 2005; Faria, 2006). Seed longevity, maturity, genetic traits, as well as environmental factors such as

moisture content, gases, temperature and light affect seed quality including germination (King and Roberts, 1980; Hadidi, 1996). According to Walsh *et al*. (2003) storage conditions such as temperature, humidity and gases are the main factors that cause genetic erosion of seed in genebanks. Simic *et al.* (2007) enumerated several factors such as pests and diseases infection, seed oil content, seed moisture content, mechanical damage, seed longevity, packaging, pesticides, air temperature and relative humidity as factors responsible for quality decline in seed under storage.

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The initial quality of seed could remain the same or decline to unacceptable levels for planting purposes during storage. Neergaard (1979), FAO (1981) and George (1985) reported that temperature and relative humidity are the most important factors influencing seed storability. Simic *et al.* (2007) reported that the longevity of maize, soybean and sunflower seed is greatly influenced by unfavourable storage conditions particularly temperature and relative humidity which tend to accelerate seed deterioration independent of the initial seed quality. King and Roberts (1980) stated that the longevity of recalcitrant seeds is generally short, particularly, species adapted to tropical environment, whilst those adapted to temperate environment live relatively longer.

2.3.1 EFFECT OF TEMPERATURE ON SEED QUALITY

The effect of temperature on the retention of tree seed viability has been thoroughly investigated by many authorities. Tanaka, (1984) and McCormack (2004) indicated that for better viability retention, seeds should be stored at -18°C Neergaard (1979 recognized three cardinal temperatures, 0 -5 °C, 30 -33 °C, and 50 -55 °C that governed the growth of most storage fungi which in turn caused seed to deteriorate. It was further indicated that between

12-15°C, most storage fungi grow slowly in cereals, and almost cease growing at 5-8 °C and 15-16 % moisture content (Neergaard, 1979).

Wheat and maize seeds did not deteriorate in a year when stored between temperatures of 5-10 °C and 15-16 % moisture content and that maize seed stored at 5 °C germinated 100 % after 2 years of storage (Neergaard, 1979). Copeland and McDonald (2001) reported that *Dendrocalamus stratus* seeds lost viability within six months when stored under ambient room temperature conditions but retained viability when stored at 0°C in sealed polythene bags. The authors further noticed that *Cederus deodara* seeds stored at high moisture content lost viability in 2 months but remained viable over 6 months when stored at reduced moisture content and temperature of 3°C to 5°C (Copeland and McDonald, 2001).

High temperatures affect the germination of both old (3-5 years) and new (6 months) seeds (Ojeda and Trione, 1990). The authors observed that high temperatures affect. Copeland and McDonald (2001) recognised two broad biogeographical divide as temperate and tropical seeds, and stated that those of the latter eco-zone suffer chilling injury and loss of germination if temperatures fall below 10°C.

2.3.2 EFFECT OF HUMIDITY ON SEED QUALITY

Even though seed inexorably deteriorates in storage, poor storage conditions can adversely affect seed longevity, germination and seedling vigour (Agrawal, 1995; Cantliffe.1998). Germination and seedling vigour are severely affected if seed is stored at high relative humidity and deterioration is much faster if the storage temperature is also high (Cantliffe, 1998). The equilibrium moisture content determines the fungi that grow on the seed in storage with some surviving at 65-70% and others at 85 -90% (FAO, 1981). Cereal seeds

stored at 13-18 % moisture content in a high relative humidity room produced a vapour pressure at 70-73% that is enough to support *Aspergillus halophilicus* growth (Neergaard, 1979). It was further observed that pea seeds stored at 85% relative humidity and 30 ^{o}C lost germination completely in six months (Neergaard, 1979).

Some seeds cannot survive desiccation beyond some levels if germination must be maintained. These seeds (recalcitrant seeds), as reported, are better stored under high relative humidity conditions and striking examples include the *Mangifera indica* (40%), and *Theobroma cacao* (17-27%, Fu *et al.*, 1990).

2.2.3 EFFECT OF PACKAGING ON SEED QUALITY

A good number of containers are used for storing seeds but their suitability depends on the kind or type of seed and the protection the container can offer the seed in storage. Robbins and Shetha (1986) reported that un-extracted fruit seeds should not be stored in sealed containers or in deep piles. It is recommended that seed be packaged in smaller units to avoid risk of physical gradients, particularly vapour pressure, which arise in large bulks (George, 1985; Agrawal, 1995). Classifying packaging materials, Agrawal (1995) categorised packaging materials into three; (1) moisture-vapour permeable containers (e.g. jute sack). (2) moisture-vapour resistant containers (e.g. Jute lined with polythene film) and (3) moisture-vapour proof containers (tin cans, polythene). The author further recognised three types of polythene used for storing seed; the low, medium and high density, and stated that the low density polythene (200 µm) is considered more satisfactory for seed storage (Agrawal, 1995). Tanaka (1984) and McCormack (2004) also agreed that most frequently used storage containers are plastic bottles with screw tops, polyethylene bags, and fibreboard drums. The

authors recognized that they are relatively inexpensive and provide an effective barrier to exchange of moisture by seed with the atmosphere.

2.3.4 EFFECT OF SEED MOISTURE CONTENT ON QUALITY

Safe storage of an agricultural commodity depends largely on its moisture content, temperature and storage period. Sastry *et al*. (2007) reported that low moisture content reduces respiration and deterioration and thereby improves stored seed quality. In storage, grains are influenced by air movement within the grain sometimes resulting in moisture condensation and mould spoilage (Anon, 1996). The length of the intended storage period is of prime importance as the maximum moisture levels need to be modified for safe storage. It was also reported that for safe storage of barley for one year, the maximum moisture level of 13% is required whereas 11% is required for five years (Anon, 1996).

2.3.5 EFFECTS OF SEED OIL CONTENT ON QUALITY

Tweneboah (2000) reported that plants generally produce two kinds of oil: the fixed, non-volatile and volatile ‘essential’ oil which serve as food reserves or stored energy in the plant, and are mainly found in the seed. Oladimeji and Kolapo (2008) listed physic nut (*Jatropha cucas*) together with soybean (*Glycine max*), groundnut (*Arachis hypogea*), Cashew (*Anacadiem occidentale*) and coconut (*Cocos nucifera*) as the world most prominent oil crops. Tweneboah (2000) reported that seed oil is mostly stored in the cotyledons, and so increase in cotyledon size may lead to increased oil concentration in whole seed, provided compensatory changes in non-oil bearing tissues are minimized. Jatropha seeds contain oil in high quantities that can be extracted for industrial purposes (Heller, 1996; Gorge, 2003). Copeland and McDonald (2001) observed that the oil content in seed influences the equilibrium moisture content and seed storage life and reported that those high in

carbohydrates are hydrophilic whilst those high in oil content are hydrophobic. However, when provided with certain necessary storage conditions, oilseeds storage life may be extended. This was observed by Daun (1995) who recommended that oilseeds storage for extended period is only possible if the seed moisture content is less than 10 % or preferably dried to 8 %.

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CHAPTER THREE

3.0 MATERIALS AND METHODS

The experiment was conducted at the Department of Horticulture, Kwame Nkrumah University of Science and Technology with trials set up in the laboratory, in the plant house and on the research plots of the Department. Two field trials were conducted in both the rainy and dry seasons between April—July and September--November, 2007 respectively. Weather conditions during the experiment are shown in appendix 2.

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3.1 SEED COLLECTION AND PROCEESSING

The experimental materials were the *Jatropha curcas* seeds collected from three agroecological zones in Ghana. Mature fruits of *Jatropha curcas* were harvested in the Guinea Savannah, Forest and Coastal Savannah ecozones of Ghana. The fruits were collected from plants of different ages when pods were brown ripe. The pods were then manually cracked by hand and the seeds extracted. The seeds were air-dried in a room for about two weeks. This reduced the harvest moisture content from 18.1 % to about 17.2 %. The seeds were then stored for six months under ambient room and in a cold store conditions. Samples were drawn at the end of each month for viability test and at the end of the sixth month for oil content and health test.

3.2 LOCATION AND SITE OF EXPERIMENT

The site of the experiment is located on Latitude $6^{o}745'$ N and longitude $01^{o}36'$ W (Anon. 1977). The site experiences both dry and rainy season in a year. The rainy (main) season begins in April and ends in July followed by a dry spell in August. The minor season follows next from September to October proceeding the dry season which occurs between December and March (Dickson and Benneh, 1970).

3.3 CLIMATIC DATA.

Data on the weather conditions during the experimental period was obtained at the KNUST Sub-Meteorological Station near the Department of Animal Science (Appendix II). The temperature (T^o) and relative humidity (RH) of the store room were also recorded during the seeds storage period. The Cold store was maintained at 90% relative humidity and at the temperature of 10 – 15 ^oC throughout the storage period.

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3.4 SEED ASSESSMENT

This involved the examination of seeds in order to determine the quality status of the seed lots collected from the three agroecological zones. The qualitative parameters measured were: number of seeds per pod, seed shell to kernel ratio, 1000 seed weight, seed health status, viability, seed oil content and seed storability.

3.4.1 NUMBER OF SEEDS PER POD

Five hundred pods or fruits were randomly drawn from each location and the seeds extracted. The number of seeds realised after cracking the pods (A) was divided by the number of pods cracked (B) to give the number of seeds per pod i.e. $N = A/B$.

Where, N is the number of seeds per pod.

A is total number of seeds obtained after cracking.

B is the number of pods sampled.

3.4.2 SEED SHELL TO KERNEL RATIO

Seed shell to kernel weight ratio (S) was determined by counting 100 seeds in five replications. The initial weight in grams (Wi) was determined and the seeds cracked. The kernel weight (K) was determined after cracking and the difference in weight, representing

the shell weight (Sw) computed. The average weights of the seed kernel and that of the shell were expressed as a ratio using the function: S = (K/Sw).

3.4.3 THOUSAND (1000) SEED WEIGHT

Seeds from the three different locations were counted in eight replicates of hundred (100) seeds per location and weighed (ISTA, 2007). The variance, standard deviation and coefficient of variation were calculated according the formula below:

Variance = $N(\Sigma X^2) - (\Sigma X)^2/N(N-1)$.

Where, X = weight of each replicate in grams.

N = Number of replicates

Standard deviation(s) = √Variance.

Coefficient of variation = $S/\mu \times 100$

Where μ = mean weight of 100 seeds.

From the eight replicate weights of 100 seeds, the average weight of 1000 seeds was calculated from the formula, $(10 \times \mu)$, as suggested by ISTA (1993).

3.4.4 SEED HEALTH TEST

Seed health test was carried out in the mycology laboratory of CSIR - Crop Research Institute, Fumesua near Kumasi using the blotter method which involved plating and incubating seeds. Ten seeds were placed on a well soaked filter paper per Petri dish and incubated for 7 days at 22 ^{o}C under 12 hours of alternating cycles of light and darkness (ISTA, 2003). Two hundred seeds per sample were used for the test. On the 7th day, the fungi fruiting bodies on the seeds were examined under different magnification of a compound microscope and a stereomicroscope and the different fungi species identified and recorded.

3.4.5 GERMINATION TEST

Germination tests were carried out on the stored seed lots for six consecutive months. An initial germination percentage per lot was determined before drying the seed to 10% and 8% moisture levels. Sterilized soil in the ratio of 1:1 (black soil to sand) as suggested by Ginwal *et al* (2005) was used for the seed germination tests in earthen clay pots.

Fifty (50) seeds were uniformly placed in the germination pan at three replications and placed in a plant-house. The soil was kept moist by routine watering as suggested by Agrawal (1995). Also, the soil was replenished each time the test was conducted (ISTA, 1993) to avoid residual and/or cross infection by pathogens. The seedlings were moved from the plant-house outside for light radiation on the 5^{th} day after sowing until the 14^{th} day. Daily germination counts were taken and recorded up to the fourteenth day (time after which no seed was observed to have germinated). The results were calculated as percentage normal seedlings (ISTA, 1979).The abnormal seedlings and dead seeds percentages were also computed.

3.4.6 SEED MOISTURE CONTENT

Moisture content of the seeds collected was determined by means of an electronic moisture meter. The electronic moisture meter was calibrated by the oven dry-method before usage. The moisture content of the seeds from each location was replicated ten times and the average recorded. The seeds were dried from an average initial moisture content of 17.5% to 10% and 8% using the humidifier dryer and sealed off in 200µm thick polythene bags as recommended by Sinnadurai (1992).

3.4.7 SEED VIGOUR AND SEEDLING GROWTH RATE

Two determinations were made to assess seed vigour and growth rate: The first count was carried out on the fourth day after sowing and the vigour index computed (Powell and Matthews, 1995).

The above ground dry biomass of the seedling was also measured to determine seedling growth rate as an indicator of seed vigour. This measurement began on the 14th day after sowing was repeated at weekly intervals for four weeks. The fresh weight of ten seedlings was determined, oven-dried at 105 ^{0}C for 17 hours (Agrawal, 1995) and then re-weighed after cooling for about 30 minutes. The determination was repeated monthly for six months.

3.4.8 SEED OIL CONTENT

Seed oil content was determined by the Kedjahl Oil (Ether) Extraction Method (AOAC, 1990). The tests were carried out on samples taken before and after seed storage.

3.4.9 SEED STORABILITY

After drying to 10 % and 8 % moisture contents, about 400 seeds were put into a polythene bag of thickness 200 µm, and hermetically sealed off as recommended by Sinnadurai (1992). In all, 84 sachets of seed were obtained to cater for both monthly routine germination tests and mycology analysis at the end of the storage period. The 84 samples were divided into two, and each batch comprising 42 sachets from the three seed collection zones were stored under two different storage conditions: the ambient room storage temperature between 24 ^{0}C and 32 ^{0}C with relative humidity ranging from 72 % to 96 % and cold storage which was between 10 ^{0}C and 15 ^{0}C with relative humidity of 90 %.

3.5 FIELD TRIAL

3.5.1 EXPERIMENTAL DESIGN AND FIELD LAYOUT

The first trial consisted of six treatments replicated three times in a Randomized Complete Block Design (RCBD).The treatments were the seedlings raised from the seeds collected from the three locations that had been dried to the two different moisture levels (8% and 10%). The second trial consisted of twelve treatments comprising the same six treatments which were further divided in two and stored under two different storage conditions namely, ambient room and cold storage. The moisture content (mc) of the seed samples and storage conditions are indicated in Appendix 1.

3.5.2 PLANTING OUT

Soil (made up of two parts black soil and one part river sand) was used to fill polythene bags, which were then thoroughly watered and allowed to stand for 24 hours. Healthy looking seedlings with two true leaves were potted into the filled polythene bags containing the moist soil on the 1st of April, 2007 for the first trial and on the 3rd of August, 2007 for the second trial. Ten seedlings per treatment were arranged on each plot of dimensions 4m × 1m at the spacing, 80cm × 60cm in the field. This gave a total number of 180 plants in an area of 98.4 m^2 at the first trial and 360 plants in 196.8 m^2 at the second trial. The plants were at the two-true-leaf stage at the time of transplanting.

3.5.3 CULTURAL PRACTICES

Agronomic practices carried out during the trial period included weeding, irrigation, fertilizer application and disease control. The field was kept weed-free through manual hoeing. Supplementary irrigation was carried out to keep the soil sufficiently moist during the trial

period. Nitrogen was applied in the form of ammonium sulphate at the eighth week at the rate of 5gm per plant (50-60 gm N per plants per year) (www.svele.com/jatropha_plant, 2005).

A spray of biobit (acaricide-fungicide) solution at the rate of 1.5 L/ha active ingredient was used to control the incidence of fungal infection that occurred on the leaves of the plants (during the two different trial periods). The spray was applied using a pneumatic Knapsack sprayer.

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3.5.4 PARAMETERS FOR ASSESSMENT

Plant growth measurements were taken on all ten plants per plot fortnightly beginning from April for ten weeks. The experiment lasted for twenty weeks from April to September, 2007 since it was repeated a second time.

3.5.4.1 MEAN PLANT HEIGHT

Plant height was measured fortnightly. This began from the first week after planting. The plant height was taken at the soil level in the polythene bag containing the plant. The average plant height per treatment was computed and recorded.

3.5.4.2 MEAN PETIOLE LENGTH

Petiole length of the plant was measured. The measurement was carried out on the second true leaf. This was repeated fortnightly for ten weeks whiles the plants were in the field.

3.5.4.3 MEAN NUMBER OF LEAVES

Cumulative number of leaves over the ten-week period for each time of the trial was recorded. Only fully developed or expanded leaves were counted at two weeks intervals and

recorded. This began from the first week of planting. Leaf drop was noted and recorded. The leaf count was carried out in the mornings between 6am and 9am.

3.5.4.4 MEAN LEAF AREA

Leaf area was measured using a 30cm ruler. The length (L) was taken along the midrib of the leaf from the point of attachment to the petiole to the end of the leaf parallel-wise. The breath (B) was measured using the maximum width of the leaf (Wilhelm *et al*., 2000; Bull, 1968). All measurements were taken between 6am and 9am. The leaf area (LA) was estimated for each plant from the empirical relationship: LA = (Lx B) x 0.74. Leaf area index (LAI) was computed by dividing the quotient by the area of ground occupied by a plant (Waldir *et al*, 2001; Bull, 1968).

3.5.4.5 MEAN NUMBER OF NODES

Stem nodes were observed, counted and recorded every two weeks during the ten-week period of the plants in the field. The same measurement was repeated during the second trial. Careful observation was made as to whether blind nodes (i.e. nodes other than at sites of leaf axils) developed. The sites of nodes were observed for branch development during the period as the plants grew.

3.5.4.6 MEAN INTERNODE LENGTH

Mean internode length of the plant was recorded during the ten-week period as an indicator of stem growth. A 5m rule was used to record the lengths. The exact distance between the first and the second true leaf was measured and recorded. This began in the first week after planting and lasted over the ten weeks duration for each trial.

3.5.4.7 MEAN STEM DIAMETER

The Veneer Calliper was used in measuring stem diameter. Beginning from the first week, the stem diameter was repeatedly measured fortnightly for the ten-week period. The measurements were taken at the full height of the polythene bags in which the plants were planted. This measurement indicates stem lateral growth. The same steps were repeated during the second trial.

3.5.4.8 MEAN PLANT CANOPY

Plant canopy was measured at fortnightly interval for ten weeks. Two perpendicular distances covered by the plant canopy were measured using a 5m rule and recorded. The average of the two measured lengths gave the diameter of the canopy.

3.5.4.9 MEAN NUMBER OF BRANCHES

The plants were observed for any branch development during the trial period in the field.

3.6 ANALYSIS OF DATA

The Genstat statistical package was used to analyse the data and means were separated by the Lsd. However, data on seed vigour index and velocity of germination were transformed by the arc sine before analysis.

CHAPTER FOUR

4.0 Results

4.1 Seed characteristics of *Jatropha curcas*

The characteristics of *Jatropha curcas* seed collected from the Coastal Savannah, Forest and Guinea Savannah Zones in Ghana are reported below. These characteristics comprise: number of seeds per pod, seed oil content, germination percentage, seedling dry weight, seed kernel to shell ratio and fungi associated with the seed.

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4.1.1 Number of seeds per pod

Number of seeds per pod/fruit determined at harvest is presented in Table 4.1. The result indicated that *J. curcas* fruit inherently developed three loci that contain an average of three seeds. The zones (Coastal Savannah, Forest and Guinea Savannah Zones) from where the seeds were collected did not differ significantly in the number of seeds per pod, though there were fewer seeds per pod, on the average, in the collection from the Guinea Savannah zone.

Table 4.1 Number of seeds per fruit of *Jatropha curcas* from the three zones.

Zone of seed collection	No. of pods/sample	No. of seeds after cracking	Seed/pod ratio
Coastal Savannah Zone	500	1500	3.00
Forest Zone	500	1500	3.00
Guinea Savannah Zone	500	1499	2.99

4.1.2 Seed germination and seed oil content at harvest

Germination of *J. curcas* seeds were similar among the three zones. Inaddition, seed oil content at harvest did not also differ significanlty among the three zones.

4.2 Effect of seed drying on seed characteristics of *Jatropha curcas*

Table 4.2 to 4.6 show the results of thousand seed weight, seed oil content, seed germination and vigour, seedling field establishment and fungi on *J. curcas* seed as affected seed drying.

4.2.1 Thousand seed weight

Seeds from the Forest Zone dried to 10% moisture content were 7.7% significantly heavier than seeds from the Coastal Savannah dried to 8% moisture content. The lightest seeds were obtained from the Guinea Savannah Zone dried to 8% moisture content (Table 4.2). At 10% moisture content the seeds were 0.50% heavier than when dried to 8% moisture content.

Table 4.2 Effect of seed drying on thousand seed weight of *Jatropha curcas* from the three zones.

Zone of seed collection	Thousand seed weight 8% m.c	10% m.c.	Mean
Coastal Savannah Zone	650.9	651.5	696.4
Forest Zone	690.9	701.3	581.6
Guinea Savannah Zone	572.1	591.3	651.7
Mean	641.4	644.6	
Lsd (p>0.05%)	zone = 8.55 m.c. = 9.87 zone x m.c. = 17.10		
CV%	1.6		

4.2.2 Percentage seed oil content after seed drying

Oil content of *J. curcas* after drying the seed is shown in Table 4.3. At 8% seed moisture level, oil content was the same for seeds collected from the Coastal Savannah and Guinea Savannah Zones but they differed significantly from oil content of seeds from the Forest Zone dried to 8% moisture content ($P > 0.05$). When dried to 10% moisture content, there were no significant differences in seed oil content among seeds from the three zones.

Table 4.3 Effect of seed drying on percentage seed oil content *Jatropha curcas* from the three zones.

Zone of seed collection	Percentage seed oil content 8%m.c	10%m.c.	Mean
Coastal Savannah Zone	43.55	51.80	47.67
Forest Zone	51.46	53.17	52.32
Guinea Savannah Zone	43.29	52.98	48.13
Mean	46.10	52.65	
Lsd (p>0.05%)	zone = 2.46	m.c. =2.01	zone x m.c. = 3.47
Cv%	2.9		

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4.2. 3 Seed germination after seed drying

Germination percentage determined after drying the *J. curcas* seed is shown in Table 4.4. Seeds from the Forest Zone germinated 31.4 % more than seeds from the Coastal Savannah at 10% moisture content and Guinea Savannah Zones at 8% moisture content ($p<0.05$). There were no significant differences in germination between seeds from the Guinea Savannah and Coastal Savannah Zones. At 10% moisture content, seed germination was higher by 1.0% than when the seeds were dried to 8% moisture content.

Table 4.4 Effect of seed drying on percentage germination of *Jatropha curcas* seed from the three zones.

Zone of seed collection	Percentage seed germination 8%m.c	10%m.c.	Mean
Coastal Sav. Zone	69.6	68.3	68.9
Forest Zone	88.3	90.7	89.5
Guinea Savannah Zone	68.8	70.3	69.5
Mean germ. %	75.6	76.4	
Lsd (p>0.05%)	zone = 2.8	m.c. =3.3	zone x m.c. = 5.7
CV%	13.8		

4.2.4 Vigour index after seed drying

Table 4.5 shows the vigour index of *J. curcas* seed. Seeds from the Forest Zone dried to 10% moisture content produced at least 16.8% significantly higher vigour index than seeds from the Coastal Savannah and Guinea Savannah Zones ($p<0.05$). There were no significant differences in vigour index between seeds from the Coastal Savannah and Guinea Savannah Zones. The seeds were 3.7% significantly vigorous when dried to 10% moisture level than at 8% seed moisture content.

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Table 4.5 Effect of seed drying on vigour index of *Jatropha curcas* seed from the three zones.

Zone of seed collection	Seed vigour index 8%m.c.	10%m.c.	Mean
Coastal Sav. Zone	6.48	6.72	6.60
Forest Zone	7.79	7.85	7.82
Guinea Sav. Zone	6.06	5.88	5.97
Mean	6.77	6.81	
Lsd (p>0.05%)	zone = 0. 48	m.c. = 0.56	zone x m.c = 0.97
Cv%	8.5		

4.2.5 Seedling dry weight after seed drying

Seedling dry weight is shown in Table 4.6. Seedlings from seeds from the Coastal Savannah Zone dried to 10% moisture content produced significantly 24% heavier seedlings than those from the Forest Zones dried to 8% moisture content ($p<0.05$). There were no significant differences in seedling dry weight between seedlings from seeds collected from the Coastal Savannah and Guinea Savannah Zones.

Table 4.6 Effect of seed drying on seedling dry weight of *Jatropha curcas* from the three zones

Zone of seed collection	Seedling dry weight 8%m.c.	10%m.c.	Mean
Coastal Sav. Zone	1.23	1.29	1.26
Forest Zone	1.04	1.06	1.05
Guinea Sav. Zone	1.25	1.21	1.23
Mean	1 24	1.18	
Lsd (p>0.05%)	zone = 0.08	m.c= 0.09	zone x m.c. = 0.16
CV%	9.6		

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4.2.6 Seedling establishment in pot in the field

Growth parameters of potted *J. curcas* plants measured in the field are presented in Tables 4.7 to 4.12. These growth parameters assessed included: plant height, internode length, petiole length, stem diameter, number of leaves, leaf area, number of nodes and number of branches.

4.2.6.1 Plant height

Jatropha curcas plants grown showed that plants from seeds from the Forest Zone dried to 10% moisture content were 1.66cm significantly taller than the shortest plants from seeds from the Guinea Savannah Zone dried to 8% moisture content ($p > 0.5$; Table 4.7). There was no difference in plant height between plants of seed from the Guinea Savannah and Coastal Savannah Zones except when the seeds were dried to 10% from the latter zone. At 10% seed moisture, plants were 0.11cn significantly taller than when the seeds were dried to 8% moisture content.

Table 4.7 Effect of seed drying on Plant height of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant height 8%m.c.	10%m.c.	Mean
Coastal Savannah Zone	18.92	19.04	18.98
Forest Zone	20.12	20.26	20.19
Guinea Savannah Zone	18.60	18.68	18.64
Mean	19.21	19.32	
Lsd (p>0.05%)	zone = 0.30	m.c. = 0.31	zone x m.c. = 0.53
Cv%	3.8		

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4.2.6.2 Plant internode length

Plant internode length development was significantly affected ($p<0.05$). Plants from seeds from the Coastal Savannah Zone dried to 10% moisture produced 0.09cm and 0.1cm longer internode than plants from seeds from the Forest zone dried to 10% moisture and Guinea Savannah Zone dried to 8% moisture percent respectively (Table 4.8). There are no differences in internode length between plants from the Forest and Guinea Savannah Zones. Plant internode length was 0.01cm longer when the seeds were dried to 8% than when dried to 10% moisture content.

Table 4.8 Effect of seed drying on plant internode length of *Jatropha curcas* from the three zones

Zone of seed collection	Plant internode length 8%m.c.	10%m.c.	Mean
Coastal Savannah Zone	0.92	0.87	0.89
Forest Zone	0.86	0.83	0.84
Guinea Savannah Zone	0.82	0.87	0.84
Mean	0.86	0.85	
Lsd (p>0.05%)	zone = 0.04	m.c. = 0.03	zone x m.c. = 0.06
Cv%	9.6		

4.2.6.3 Plant stem diameter

Table 4.9 shows the stem diameter of *Jatropha curcas* plant. The highest stem diameter by plants from seeds from the Coastal Savannah dried to 10% moisture content was 0.06cm significantly thicker ($p<0.05$) than the stem diameter of plants from seeds from the Forest Zone dried to 8% and 0.03cm than plant diameter from the Guinea Savannah Zone at both 8% and 10% moisture content. When the seed was dried to 10 % moisture content, plants developed 0.02 cm thicker stems than at 8 % seed moisture content.

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Table 4.9 Effect of seed drying on Plant stem diameter of *Jatropha curcas* from the three zones

	Plant stem diameter (cm)		
Zone of seed collection	8% m.c.	10%m.c	Mean
Coastal Savannah Zone	0.72	0.75	0,73
Forest Zone	0.69	0.72	0.70
Guinea Savannah Zone	0.72	0.72	0.72
Mean	0.71	0.73	
Lsd (p>0.05%)	zone = 0.02	m.c. = 0.01	zone x m.c. = -.02
Cv%	8.4		

4.2.6.4 Plant petiole length

Plant petiole length in Table 4.10 show variability among treatments ($p<0.05$). Petiole length of plants from seeds from the Coastal Savannah Zone dried to 10% moisture content was 0.74cm and 0.41cm longer than that produced by plants from seeds from the Guinea Savannah and Forest Zones dried to 8% moisture content. When the seed was dried to 10 % moisture content plant petiole length was longer than at 8% seed moisture content by 0.28cm

Table 4.10 Effect of seed drying on Plant petiole length of *Jatropha curcas* from the three zones

	Petiole length (cm)		
Zone of seed collection	8% m.c.	10%m.c.	Mean
Coastal Savannah Zone	6.35	7.02	6.68
Forest Zone	6.61	6.82	6.71
Guinea Savannah Zone	6.28	6.52	6.40
Mean	6.42	6.70	
Lsd (p>0.05)	zone = 0.20	m.c. = 0.16	zone x m.c. = 0.28
Cv%	8.4		

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4.2.6.5 Number of leaves

Table 4.11 shows the number of leaves of *Jatropha curcas* plant which differ significantly ($p<0.05$). Plants from seeds from the Guinea Savannah Zone dried to 10% moisture content produced 8.3% more leaves than plants from seeds from the Forest Zone dried to 8% moisture level. There were no differences in leaf number between plants from the Forest and Coastal Savannah Zone. Seeds dried to 10% moisture content produced 1.7% more leaves than when dried to 8% moisture content.

Table 4.11 Effect of seed drying on number of leaves of *Jatropha curcas* plant from the three zones

Zone of seed collection	Number of leaves		
	8% m.c.	10% m.c.	mean
Coastal Savannah Zone	5.20	5.27	5.23
Forest Zone	5.16	5.20	5.19
Guinea Savannah Zone	5.06	5.58	5.32
Mean	5.14	5.29	
Lsd (p>0.05)	zone = 0.31	m.c. = 0.36	zone x m.c. = 0.63
CV%	17.0		

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4.2.6.6 Number of leaf buds after seed drying

Leaf bud number development was significantly different ($p<0.05$). Plants from seeds from the Coastal Savannah Zone dried to 10% moisture content produced the highest number of leaf buds which was 32.9% and 24.7% more than leaf buds of plants from seeds from the Guinea Savannah Zone dried to 8% moisture content and Forest Zone dried to 8% moisture content (Table 4.12). When the seeds were dried to 10% moisture content, number of bud was significantly more by 10.3% than when the seeds were dried to 8% moisture content.

Table 4.12 Effect of seed drying on the number of leaf buds of *Jatropha curcas* plant from the three zones.

Zone of seed collection	Leaf bud number		
	8% m.c.	10% m.c.	mean
Coastal Savannah Zone	8.22	9.48	8.85
Forest Zone	7.60	8.62	8.11
Guinea Savannah Zone	7.13	8.44	7.78
Mean	7.65	8.84	
Lsd (p>0.05)	zone = 0.74	m.c. = 0.86	zone x m.c. = 1.49
CV%	27.2		

4.2.7 Fungi survival on *Jatropha curcas* seed after drying

Ten (10) fungi species were detected on the *J. curcas* seed after drying. The infection levels of *Aspergillus niger, Curvularia lunata, Fusarum palledoroseum, F. semitectum, F. solani* and *Penicillium sp* were not different among seeds from the three ecological zones ($p>0.05$). However, infection levels of four fungi; *Aspergillus flavus, Collectotrichum dermatium, Fusarium oxysporium and Cladosporium sphaerospermum* differed significantly ($p<0.05$).

4.2.7.1 *Aspergillus flavus* survival on *Jatropha curcas* seed after drying

Table 4.13 shows that the infection levels of *A. flavus* on *Jatropha curcas* seeds were significant ($p<0.05$). Seeds from the Forest Zone dried to 10% moisture content were 25.7% more infected than seeds from the Coastal Savannah Zone dried to !0% moisture content. Seed from the Guinea Savannah Zone dried to 8% moisture content was 24.8% significantly more infected compared with seed from the Coastal Savannah dried to 10% moisture content. Seeds dried to 8

Table 4.13 Effect of seed drying on *Aspergillus flavus* survival on *Jatropha curcas* seed from the three zones.

Zone of seed collection	*A. flavus* infection level		
	8%m.c.	10%m.c.	Mean
Coastal Savannah Zone	2.48	2.21	2.34
Forest Zone	2.73	2.78	2.75
Guinea Savannah Zone	2.76	2.67	2.71
Mean	2.66	2.55	
Lsd ($p > 0.05$) zone = 0.32	m.c. = 0.12	zone x m.c. = 0.21	
CV% 11.8			

4.2.7.2 *Collectotrichum dermatium* survival on *Jatropha curcas* seed after drying

Infection level of *C. dermatium* on *Jatropha curcas* seed differed significantly (p>0.05). Seed from the Forest Zone dried to 8% moisture content showed 1.0% higher level of infection of *C. dermatium* than seeds from the Guinea Savannah and Coastal Savannah Zones when seeds from both zones were dried to 8% and 10% seed moisture content. When the seed was dried to 8% moisture content, it showed 1.3% more *C. dermatium* infection than at 10% moisture content (Table 4.14).

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Table 4.14 Effect of seed drying on *Collectotrichum dermatium* survival on *J. curcas* seed from the three zones.

	C. dermatium infection level		
Zone of seed collection	8%m.c.	10%m.c.	Mean
Coastal Savannah Zone	0.70	0.70	0.70
Forest Zone	0.77	0.74	0.75
Guinea Savannah Zone	0.70	0.70	0.70
Mean	0.73	0.72	
Lsd (p>0.05) zone = 0.04	m.c.% = 0.03	zone x m.c. = 0.05	
Cv% 5.3			

4.2.7.3 *Fusarium oxysporum* survival on *Jatropha curcas* seed after drying

Table 4.15 shows *F. oxysporum* infection level on *J. curcas* seed. Seeds from the Forest Zone at 8% moisture content recorded 83.3 % and 39.8% more *F. oxysporum* infection levels than seeds from the Guinea Savannah Zone dried to 8% moisture and the Coastal Savannah Zone dried to 10% moisture content respectively (p>0.05). At 8 % seed moisture, more than 17.4% of seeds were infected with *F. oxysporum* than when the seed was dried to 10% moisture content.

Table 4.15. Effect of seed drying on *Fusarium oxysporum* survival on *Jatropha curcas* seed from the three zones.

Zone of seed collection	*F. oxysporum* infection level 8%m.c.	10%m.c.	Mean
Coastal Savannah Zone	1.29	1.08	1.18
Forest Zone	1.65	1.05	1.35
Guinea Savannah Zone	0.90	1.15	1.03
Mean	1.28	1.09	
Lsd (p>0.05) zone = 0.11	m.c, = 0.20	zone x m.c. = 0.35	
Cv% 19.6			

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4.2.7.4 *Cladosporium sphaerospermum* survival on *Jatropha curcas* seed after drying

Table 4.16 show the infection levels of *Cladosporium sphaerospermum*. *Jatropha curcas* seeds from the Forest Zone dried to 8% moisture content recorded significantly 82.2% higher infection level of *Cladosporium sphaerospermum* compared with seeds from the Guinea Savannah Zone dried to 8% moisture content and 60% more than seeds from the Coastal Savannah Zone dried to 10% moisture content (p>0.05). When the seeds were dried to 10% *Cladosporium sphaerospermum* infection was reduced by 12 %.

Table 4.16 Effect of seed drying on Cladosporium *sphaerospermum* survival on *Jatropha curcas* seed from the three zones.

Zone of seed collection	*Cladosporium sphaerospermum* infection level		
	8%m.c.	10%m.c.	Mean
Coastal Savannah Zone	1.05	0.90	0.98
Forest Zone	1.44	1.16	1.30
Guinea Savannah Zone	0.79	0.81	0.80
Mean	1.09	0.95	
Lsd (p>0.05)	zone = 0.22	m.c. = 0.18	zone x m.c. = 0.32
CV%	20.9		

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4.3 Effect of storage conditions on *Jatropha curcas* seed quality

Seeds of *J. curcas* from the Forest, Guinea Savannah, and Coastal Savannah Zones dried to 10% and 8% moisture levels were stored over six months and the quality assessed. Specifically, seed oil content, germination percentage, seedling dry weight, seedling field establishment (growth parameters) and fungi survival on the seed were determined and are indicated in Tables 4.17 to 4.49 and Figures 4.1 to 4.2.

4.3.1 Seed oil content under ambient room storage conditions

Table 4.18 shows the seed oil content of *J. curcas* after six months storage in ambient room. Seeds from the Forest Zone dried to 10% moisture content which recorded the highest oil content was 44% significantly higher than seed oil content of seeds from the Coastal Savannah Zone dried to 8% which recorded the least (p>0.05). Seeds oil content of seeds from the Guinea Savannah Zone at 10% moisture content was 9.3% higher than that recorded by seeds from the Coastal Savannah dried to 8% moisture content.

Table 4.17 Effect of ambient room storage condition on seed oil content of *Jatropha curcas* from the three zones.

Zone of seed collection	Percentage seed oil content		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	38.21	43.73	40.97
Forest Zone	51.63	55.06	53.34
Guinea Savannah Zone	44.55	47.82	46.39
Mean	44.93	48.87	
Lsd	zone = 1.02	m.c. = 0.83	zone x m.c = 1.44
Cv%	2.6		

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4.3.2 Seed oil content under cold storage conditions

Cold store conditions after six months of storage affected *J. curcas* seed oil content significantly ($p>0.05$). Seeds from the Forest Zone dried to 10% moisture content expressed 24.7% more oil than seeds from the Coastal Savannah Zone at 10% moisture content. The oil content of seeds from the Coastal Savannah and Guinea Savannah Zones at both 8% and 10% moisture content were not different except more oil was express when seeds from the latter were dried to 10% moisture content (Table 4.17).

Table 4.18 Effect of cold storage conditions on seed oil content of *Jatropha curcas* from the three zones

Zone of seed collection	Percentage seed oil content		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	41.95	40.37	41.26
Forest Zone	50.04	50.36	50.20
Guinea Savannah Zone	45.12	50.24	47.68
Mean	46.30	47.47	
Lsd	Zone = 1.02	M.C. = 0.83	Zone x M.C = 1.44
Cv%	2.6		

4.3.3 Germination of *Jatropha curcas* seed in ambient room storage for six months

Table 4.19 show the germination percentage of *J. curcas* seed after ambient room storage. Seed from the Forest Zone dried to 8% produced 17.2% significantly higher germination than seed from the Coastal Savannah Zone dried to 8% moisture ($p>0.05$). Germination percentage did not differ between seeds from the Coastal Savannah and Guinea Savannah Zones.

Table 4.19 Effect of ambient room seed storage on germination of *Jatropha curcas* from the three zones.

Zone of seed collection	Percentage germination		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	63.6	63.0	63.3
Forest Zone	82.0	86.2	84.1
Guinea Savannah Zone	70.1	64.8	67.4
Mean	78.5	71.3	
Lsd Zone = 5.74	M.C. = 6.63	Zone x M.C = 11.48	
Cv% 13.8			

4.3.4 Germination of *Jatropha curcas* seed in cold storage for six months

Table 4.20 show the germination of *J. curcas* seed as after cold store storage. Seed from the Forest Zone dried to 8% produced 25.2% significantly higher germination percentage than seed from the Coastal Savannah Zone dried to 8% moisture ($p>0.05$). Germination percentage between seeds from the Coastal Savannah and Guinea Savannah Zones only differed when the seed from the former zone was dried to 8% moisture content.

Table 4.20 Effect of cold store conditions seed storage on germination of *Jatropha curcas* from the three zones.

Zone of seed collection	Percentage germination		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	64.9	59.1	62.0
Forest Zone	88.7	90.9	89.3
Guinea Savannah Zone	62.6	68.7	65.6
Mean	78.7	72.9	
sd zone = 5.74	m.c. = 6.63	zone x m.c. = 11.48	
Cv% 13.8			

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4.3.5 Coefficient of velocity of germination of *Jatropha curcas* seed under six months ambient room storage

Table 4.21 shows coefficient of velocity of germination of *J. curcas* seed. Seeds from the Forest Zone dried to 8% showed 48.7% significantly faster germination rate than seeds from the Coastal Savannah Zone dried to 8% moisture content. Under ambient room storage, there were no significant differences between germination rate of seeds from the Guinea Savannah and Coastal Savannah Zones ($p > 0.05$). At 8% seed moisture germination was faster than at 10% under both ambient room and cold store conditions.

Table 4.21 Effect of ambient room storage conditions on coefficient of velocity of germination of *Jatropha curcas* seed from the three zones.

Zone of seed collection	Coefficient of velocity of germination		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	7.10	7.36	7.23
Forest Zone	10.40	10.09	9.63
Guinea Savannah Zone	7.88	7.58	7.14
Mean	8.46	8.34	
Lsd	zone = 0.69 m.c. = 0.8	zone x m.c = 1.3	
Cv%	14.5		

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4.3.6 Coefficient of velocity of germination of *Jatropha curcas* seed under six months cold storage

Table 4.22 indicates the coefficient of velocity of germination of *J. curcas* seed under cold store conditions. Seeds from the Forest Zone dried to 8% moisture content were significantly 38.4% faster in germination than seeds from the Guinea Savannah Zone dried to 8% moisture content ($p>0.05$). There were no differences in germination rate between seeds from the Guinea Savannah and Coastal Savannah Zones.

Table 4.22 Effect of cold storage conditions on coefficient of velocity of germination of *Jatropha curcas* seed from the three zones.

Zone of seed collection	Coefficient of velocity of germination		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	7.73	7.19	7.46
Forest Zone	9.76	9.51	9.63
Guinea Savannah Zone	7.05	7.84	7.44
Mean	8.18	8.18	
Lsd	zone = 0.69 m.c. = 0.8	zone x m.c = 1.38	
Cv%	14.5		

4.3.7 Seedling dry weight during storage

Seedling dry weight of *Jatropha curcas* determined as an indicator of seed vigour during storage is presented in Figures 4.1 and 4.2. Seed storage conditions affected seedling dry weight significantly ($p>0.05$). Seedling dry weight increased marginally in the first month, followed by a sharp increase in weight in the second month of seed storage. Thereafter, dry weight dramatically decreased in the third month except the dry weight of seedlings from the Forest Zone which decreased in the fourth month. The heaviest weight (1.074g) which occurred in the third month were obtained by seedlings from seeds from the Coastal Savannah Zone dried to10% moisture under cold storage, followed by those from the Guinea Savannah Zone at 8% moisture (1.046g) in room storage. The heaviest and lightest seedling dry weights were obtained in the third and sixth months of seed storage respectively.

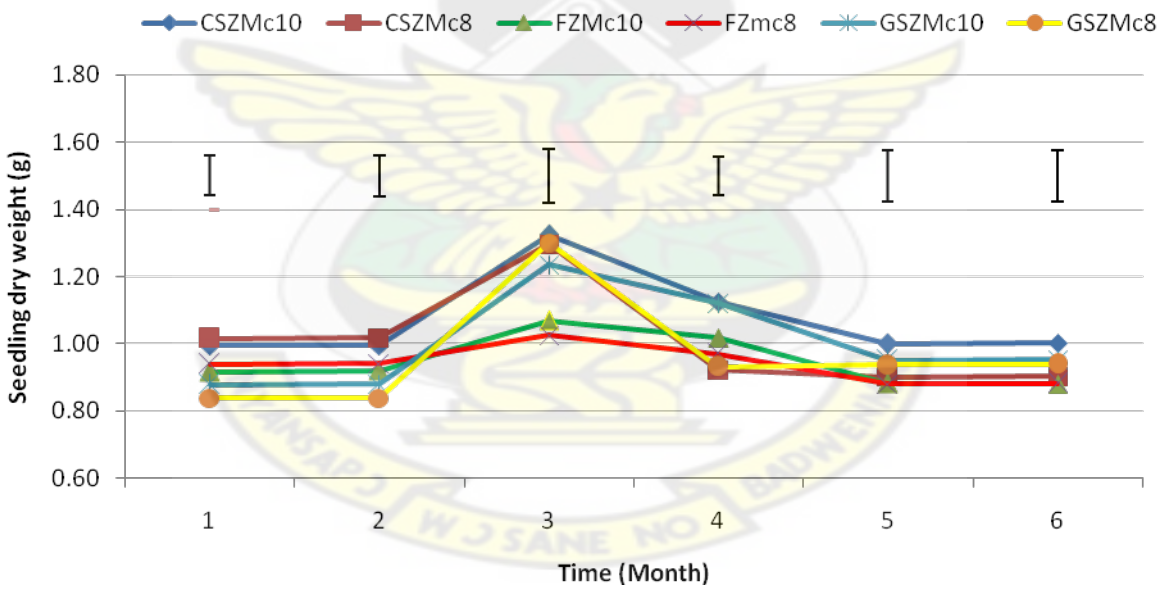

Figure 4.1 Effect of room storage conditions on seedling dry weight of *Jatropha curcas* from the three zones.

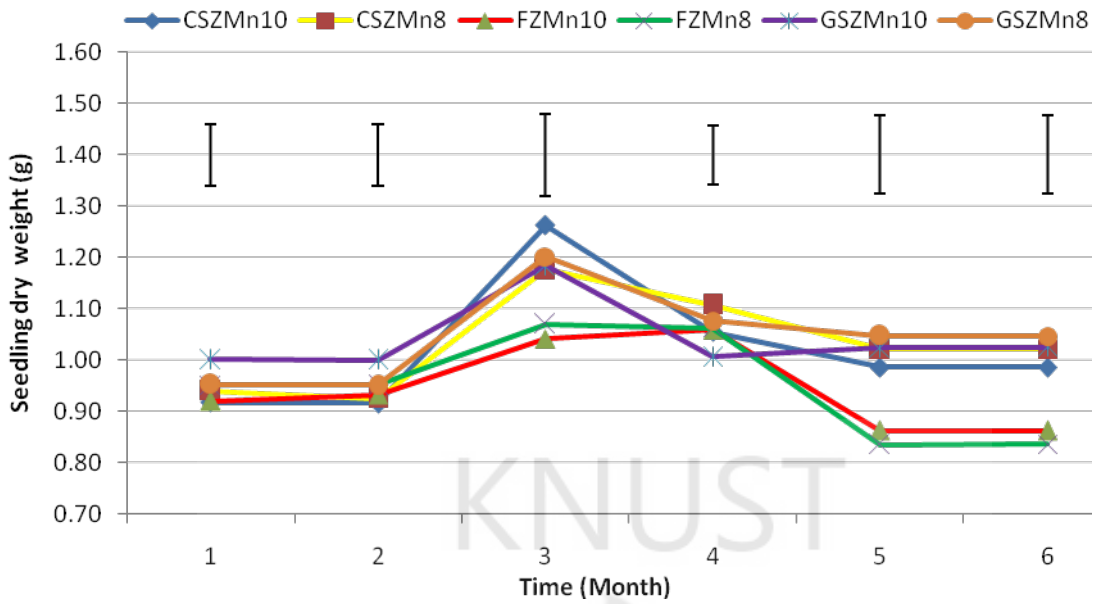

Figure 4.2 Effect of cold storage conditions on seedling dry weight of *Jatropha curcas* from the three zones.

4.3.8 Seedling establishment in the field after six months of seed storage

Growth parameters of *Jatropha curcas* plants raised after storing the seed at 8% and 10% seed moisture levels for six months were measured. The results are reported in Tables 4.23 to 4.38.

4.3.8.1 Effect of ambient room storage on *Jatropha curcas* plant height.

Plant height of *J. curcas* measured after ambient room seed storage is indicated in Table 4.23. The tallest plants from seeds from the Forest Zone dried to 8% moisture content were 2.59 cm taller than the shortest plants from seeds from the Coastal Savannah Zone dried to 8% moisture content. Plants from seeds from the Guinea Savannah and Coastal Savannah Zones were not significantly different in height ($p>0.05$) except that the height was significantly lower when the seeds from the latter zone were dried to 8% moisture content.

Table 4.23 Effect of ambient room seed storage on Plant height of *J. curcas* from the three zones.

Zone of seed collection	Plant height (cm)		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	13.44	14.65	14.04
Forest Zone	16.03	14.08	15.05
Guinea Savannah Zone	14.28	14.67	14.47
Mean	14.58	14.46	
Lsd zone = 0.41	m.c. = 0.47	zone x m.c = 0.82	
Cv% 8.8			

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4.3.8.2 Effect of cold room storage on *Jatropha curcas* plant height

Plant height of *J. curcas* measured after cold room seed storage is indicated in Table 4.24. Plants height from seeds from the Forest Zone dried to 10% moisture content was 1.20cm taller than the shortest plants from seeds from the Coastal Savannah Zone dried to 8% moisture content. Plants from the Guinea Savannah and Coastal Savannah Zones were not significantly different in height ($p>0.05$) except height was significantly higher when the seeds from the latter zone were dried to 10% moisture content.

Table 4.24 Effect of cold store conditions on plant height of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant height (cm)		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	13.33	14.41	13.87
Forest Zone	14.51	14.55	14.53
Guinea Savannah Zone	13.71	13.84	13.77
Mean	13.85	14.26	
Lsd zone = 0.41	m.c. = 0.47	zone x m.c = 0.82	
Cv% 8.8			

4.3.8.3 Plant internode Length after ambient room seed storage

Plant internode length of *Jatropha curcas* is shown in Table 4.25. Plants from seeds from the Coastal Savannah Zone dried to 8% produced significantly 0.33cm longer petiole length than plants from seeds from the Guinea Savannah Zone dried to 10% moisture content. Petiole length was not different for plants from the Guinea Savannah and Forest Zones except internode length was lower when the seed from the Guinea Savannah Zone was dried to 10% moisture content.

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Table 4.25 Effect of ambient room seed storage on plant internode length of *J. curcas* from the three zones

Zone of seed collection	Plant internode length (cm)		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	1.51	1.42	1.46
Forest Zone	1.29	1.28	1.28
Guinea Savannah Zone	1.28	1.18	1.23
Mean	1.36	1.26	
Lsd zone =0.03	m.c. = 0.04	zone x m.c = 0.07	
Cv% 8.4			

4.3.8.4 Plant internode length after cold room seed storage

Plant internode length of *Jatropha curcas* is shown in Table 4.26. Plants from seeds from the Forest Zone dried to 8% produced significantly 0.11cm and 0.09cm longer petiole length than plants from seeds from the Guinea Savannah and Coastal Savannah Zones dried to 8% moisture content respectively. When the seed was dried to 8% moisture content, petiole length was significantly longer by 0.08 cm.

Table 4.26 Effect of cold store conditions on plant internode length of *J. curcas* from the three zones.

Zone of seed collection	Plant internode length (cm)		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	1.33	1.39	1.36
Forest Zone	1.42	1.28	1.35
Guinea Savannah Zone	1.31	1.40	1.35
Mean	1.43	1.35	
Lsd zone =0.03	m.c. = 0.04	zone x m.c = 0.07	
Cv% 8.4			

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4.3.8.5 Plant stem diameter after ambient room seed storage

Stem diameter of *Jatropha curcas* plant is presented in Table 4.27. Plants from seeds stored under ambient room storage were not different in stem diameter ($p<0.05$). However, plants from seeds from the Coastal Savannah Zone dried to 10% moisture differed from plants from seeds from the Forest and Guinea Savannah Zones under cold storage (Tables 4.27 - 4.28).

Table 4.27 Effect of ambient room seed storage on plant stem diameter *Jatropha curcas* from the three zones.

Zone of seed collection	Plant stem diameter (cm)		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	0.89	0.93	0.91
Forest Zone	0.88	0.85	0.86
Guinea Savannah Zone	0.87	0.87	0.87
Mean	0.88	0.88	
Lsd zone = 0.01	m.c. = 0.02	zone x m.c = 0.03	
Cv% 7.0			

4.3.8.6 Plant stem diameter after cold store seed storage

Stem diameter of *Jatropha curcas* plant is presented in Table 4.28. Stem diameter did not differ significantly under cold storage ($p<0.05$) except when compared with plant stem diameter of seeds from the Coastal Savannah Zone dried to 10% moisture stored under ambient room storage

Table 4.28 Effect of cold store seed storage on Plant stem diameter of *J. curcas* from the three zones.

Zone of seed collection	Plant stem diameter (cm)		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	0.79	0.84	0.81
Forest Zone	0.80	0.79	0.79
Guinea Savannah Zone	0.83	0.84	0.83
Mean	0.80	0.82	
Lsd	zone = 0.01	m.c. = 0.02	zone x m.c = 0.03
Cv%	7.0		

4.3.8.7. Plant petiole length after seed storage

Plants from seeds from the Coastal Savannah Zone dried to 10% moisture content had 0.63 cm significantly longer petioles than petiole length of plants from seeds from the Guinea Savannah Zone dried to 8% moisture content ($p>0.05$). There were no significant differences between petiole length of plants from the Forest and Guinea Savannah Zones. Plant petiole length was generally longer when the seeds were stored under ambient room than in cold store (Tables 4.29 – 4.30).

Table 4.29 Effect of ambient room seed storage on plant petiole length of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant petiole length (cm)		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	6.29	6.38	6.33
Forest Zone	5.36	5.37	5.36
Guinea Savannah Zone	5.75	6.05	5.90
Mean	0.80	0.82	
Lsd	zone = 0.03	m.c. = 0.04	zone x m.c = 0.07
Cv%	8.4		

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4.3.8.8 Plant petiole length after seed storage

Plants from seeds from the Guinea Savannah Zone dried to 10% moisture content had 15.8% and 12.5% significantly longer petioles than petioles of plants from seeds from the Forest Zone dried to 10% moisture content and Coastal Savannah Zone dried to 10% moisture content respectively ($p>0.05$).

Table 4.30 Effect of cold store conditions on plant petiole length of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant petiole length (cm)		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	5.64	5.16	5.40
Forest Zone	4.50	5.10	5.30
Guinea Savannah Zone	5.02	5.81	5.41
Mean	5.05	5.32	
Lsd	zone = 0.03	m.c. = 0.04	zone x m.c = 0.07
Cv%	8.4		

4.3.8.9 Leaf number of *Jatropha curcas* plant after seed storage

Plants from seeds from the Coastal Savannah Zone dried to 10% produced the highest number of leaves which was 16% and 9.2% significantly more than number of leaves produced by plants from seeds from the Guinea Savannah Zone dried to 8% and Forest Zone dried to 8% moisture content respectively ($p>0.05$ (Table 4.31). Plants from seed stored under ambient room conditions produced more leaves than plants from seed stored under cold store conditions (Tables 4.31 and 4.32).

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Table 4.31 Effect of ambient room seed storage on plant leaf number of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant leaf number		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	6.32	6.59	6.45
Forest Zone	6.03	6.19	610
Guinea Savannah Zone	5.68	5.81	5.74
Mean	6.01	6.19	
Lsd	zone = 0.31	m.c. = 0.36	zone x m.c = 9.63
Cv%	17.0		

4.3.8.10 Leaf number of *Jatropha curcas* plant after seed storage

Under cold storage, plants leaf number did not differ significantly ($p<0.05$). Leaf number only differed between plants of seeds stored under cold condition and ambient room conditions (Tables 4.31 and 4.32).

Table 4.32 Effect of cold store conditions on plant leaf number of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant leaf number		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	5.01	5.17	5.09
Forest Zone	5.21	5.03	5.12
Guinea Savannah Zone	5.28	5.13	5.20
Mean	5.16	5.11	
Lsd	zone = 0.31	m.c. = 0.36	zone x m.c = 9.63
Cv%	17.0		

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4.3.8.11 Plant canopy spread after ambient room storage of seeds for six months

Canopy spread of *Jatropha curcas* plants from seeds stored under ambient room for six months is presented in Table 4.33. Plants from seeds from the Forest Zone at 8% produced 2.57 cm larger canopy than canopy spread of plants of seeds form the Guinea Savannah Zone at 8%. No differences in canopy spread betweens plants of seeds from the Forest and Coastal Savannah Zones.

Table 4.33 Effect of ambient room seed storage on plant canopy spread of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant leaf number		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	22.50	22.07	22.06
Forest Zone	22.74	20.94	21.84
Guinea Savannah Zone	20.17	21.56	20.31
Mean	21.80	21.52	
Lsd	zone = 0.79	m.c. = 0.65	zone x m.c = 1.12
Cv%	17.0		

4.3.8.12 Plant canopy spread after cold storage of seeds for six months

Canopy spread of *Jatropha curcas* plants from seeds stored under cold store for six months is presented in Table 4.35. Plants from seeds from the Guinea Savannah Zone at 8% produced 1.76 cm larger canopy than canopy spread of plants of seeds form the Forest Zone at 8% and 1.06cm larger than canopy spread of plants from seeds from the Coastal Savannah Zone dried to 8% moisture content. Canopy was larger when plants were raised from seeds dried to 10% moisture content than at 8% moisture content.

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Table 4.34 Effect of cold store condition on plant canopy spread of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant leaf number		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	18.76	18.95	18.85
Forest Zone	18.06	19.52	18.79
Guinea Savannah Zone	19.82	19.45	19.63
Mean	18.88	19.30	
Lsd	zone = 0.79	m.c. = 0.65	zone x m.c = 1.12
Cv%	17.0		

4.3.8.13 Leaf area index of *Jatropha curcas* plants after ambient room seed storage

Plants from seed from the Coastal Savannah Zone dried to 10% moisture content had significantly 17.4% leaf area index compared with the leaf area index of plants from seed from the Forest Zone dried to 10% moisture content and 14.1% larger leaf area index than that of plant from seeds from the Guinea Savannah dried to 8% moisture level. When plants were raised from seeds dried to 10% moisture their leaf area index was larger than at 8% moisture content.

Table 4.35 Effect of ambient room seed storage on plant leaf area index of *Jatropha Curcas* from the three zones.

Zone of seed collection	Plant leaf area index		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	9.12	9.49	9.30
Forest Zone	8.63	8.08	8.35
Guinea Savannah Zone	8.31	8.49	8.40
Mean	8.68	8.68	
Lsd	zone = 0.02	m.c. = 0.04	zone x m.c = 0 .06
Cv%	9.0		

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4.3.8.14 Leaf area index of *Jatropha curcas* plants after cold store seed storage

Plants from seed from the Guinea Savannah Zone dried to 10% moisture content had significantly 21.9% leaf area index compared with leaf area index of plants from seed from the Forest Zone dried to 8% moisture level. Leaf area index of plants from seeds from the Coastal Savannah and Guinea Savannah Zones were not different except when the leaf area index of plant from seeds from the Guinea Savannah Zone was dried to 10% moisture level.

Table 4.36 Effect of cold store seed storage on plant leaf area index of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant leaf number		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	7.70	7.77	7.73
Forest Zone	6.91	7.19	7.05
Guinea Savannah Zone	7.75	8.43	8.09
Mean	7.54	7.70	
Lsd	Zone = 0.02	M.C. = 0.04	Zone x M.C = .06
Cv%	9.0		

4.3.6.15 Leaf bud number of *Jatropha curcas* plants after ambient room seed storage

Plants from seed from the Forest Zone dried to 10% had 2.84 more leaf buds than those plants from seeds from the Guinea Savannah Zone dried to 8% moisture content. Leaf bud number of plants from the Guinea and Coastal Savannah zones was significantly higher when the seeds from both zones were dried to 10% moisture content compared at 8% moisture level.

Table 4.37 Effect of ambient room seed storage on plant leaf bud number of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant leaf bud number		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	6.99	8.63	7.80
Forest Zone	7.41	9.42	8.41
Guinea Savannah Zone	6.58	9.09	7.33
Mean	6.99	9.04	
Lsd	zone = 0.02	m.c. = 0.04	zone x m.c = 0.06
Cv%	9.0		

4.3.8.16 Leaf bud number of *Jatropha curcas* plants after cold store seed storage

Plants from seeds from the three zones dried to both 8% and 10% moisture content did not differ in leaf number except when the seeds from the Guinea Savannah Zone were dried to 8% moisture content (Table 4.25). Differences also exist when compared with leaf bud number of the seeds under ambient room storage (Tables 4.38 and 4.39).

Table 4.38 Effect of cold store seed storage on plant leaf bud number of *Jatropha curcas* from the three zones.

Zone of seed collection	Plant leaf bud number		
	8%m.c.	10%m.c	Mean
Coastal Savannah Zone	7.80	7.79	7.79
Forest Zone	7.79	7.82	7.80
Guinea Savannah Zone	7.68	7.79	7.73
Mean	7.43	7.80	
Lsd	zone = 0.02	m.c. = 0.04	zone x m.c = 0.06
Cv%	9.0		

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4.4 The effect of storage conditions on fungi survival on *J. curcas* seed

Most of the fungi identified on the *J. curcas* seed before storage persisted under both ambient room and cold store conditions. After the storage period of six months, it was observed that *Collectotrichum dermatium* was absent irrespective of the storage conditions. *Fusarium palledoroseum* and *Myrothecium verucaria* were not detected on seeds stored under room conditions, whereas *Fusarium subglutinans* was not detected on seeds stored under cold store conditions (Tables 4.39 to 4.49).

4.4.1 Survival of *Aspergillus flavus* and *Fusarium oxysporium* on *Jatropha curcas* seed after six months ambient room storage

The infection levels of *Aspergillus flavus* and *Fusarium oxysporium* in Table 4.39 show variability ($p>0.95$). Seeds from the Guinea Savannah Zone dried to 10% moisture content were 42.1% and 35.9% more infested than the seeds from the Coastal Savannah Zone dried to 8% moisture content and the Forest Zone dried to 8% moisture content respectively. For *Fusarium oxysporium*, the highest infection occurred on seeds from the Forest Zone dried to 10% moisture content and this was 110.1% and 50.8% more infested than seeds from the Guinea Savannah Zone dried to 10% and Coastal Savannah Zone dried to 8% moisture

content respectively. For both fungi species, infection level was higher at 10% seed moisture content than at 8% seed moisture content. Generally, cold store conditions promoted the survival of *Aspergillus flavus* and *Fusarium oxysporium* more than ambient room storage (Tables 4.39 and 4.40).

Table 4.39 Effect of ambient room store conditions on the survival of *Aspegillus flavus* and *Fusarium oxysporium* on *Jatropha curcas* seed from the three zones

Seed Collection zone	Fungi					
	Aspegillus flavus			*Fusarium oxysporum*		
	8% m.c.	10% m.c	Mean	8% m.c.	10% m.c	Mean
Coastal Savannah Zone	1.97	2.11	2.04	1.24	1.42	1.33
Forest Zone	2.06	2.79	2.42	0.70	1.87	1.28
Guinea Savannah Zone	2.51	2.80	2.65	1.15	0.89	1.04
Mean	2.18	2.56		1.03	1.21	
Lsd	Zone = 0.19 m.c. = 0.22 zone x m.c. = 0.39			zone = 0.23 m.c. = 0.26 zone x m.c. = 0.46		
Cv%	11.2			21.8		

4.4.2 Survival of *Aspegillus flavus* and *Fusarium oxysporum* on *Jatropha curcas* seed under six moths cold store conditions.

The infection levels of *Aspergillus flavus* and *Fusarium oxysporium* is shown in Table 4.39. Seeds from the Guinea Savannah Zone dried to 10% moisture content showed 95.5% and 25% higher significant infestation than the seeds from the Coastal Savannah Zone dried to 10% moisture content and the Forest Zone dried to 10% moisture content respectively. The infection level of the seeds from the Guinea Savannah and Forest Zones were not different except when the seeds from the latter zone were dried to 10% moisture content. For *Fusarium oxysporium*, the highest infection occurred on seeds from the Guinea Savannah Zone dried to

8% moisture content and which was 69.4% and 13.2% more infested than seeds from the Forest Zone dried to 8% and Coastal Savannah Zone dried to 10% moisture content respectively. For both fungi species, infection level was higher at 8% seed moisture content than at 10% seed moisture content. At 8% moisture content, infection was higher than when the seeds were dried to 8% moisture content for both fungi species.

Table 4.40 Effect of cold store conditions on the survival of *Aspegillus flavus* and *Fusarium oxysporum* on *Jatropha curcas* seed from the three zones

Seed Collection zone	Fungi					
	Aspegillus flavus			*Fusarium oxysporum*		
	8% m.c.	10% m.c	Mean	8% m.c.	10% m.c	Mean
Coastal Savannah Zone	2.00	1.56	1.78	1.87	1.81	1.84
Forest Zone	2.75	2.44	2.59	1.21	1.42	1.31
Guinea Savannah Zone	2.74	3.05	2.89	2.05	1.77	1.42
Mean	2.49	2.35		1.71	1.66	
Lsd	zone = 0.19 m.c. = 0.22 zone x m.c. = 0.39			zone = 0.23 m.c. = 0.26 zone x m.c. = 0.46		
Cv%	11.2			21.8		

4.4.3 Survival of *Curvularia lunata* and *Aspergillus niger* on *Jatropha curcas* seed under six moths ambient room store conditions.

The infection levels of *Curvularia lunata* and *Aspergillus niger* are shown in Table 4.41. The infection levels among seeds from the three zones were not different ($p>0.05$) except only when the seeds from the Guinea Savannah Zone were dried to 10% moisture content. It also indicated that seeds dried to 10% moisture content were more infested than at 8% moisture content. In the case of *Aspergillus niger*, infection level was more on seeds from the Forest Zone dried to 8% moisture content by 51.4% and 45.2% compared with seeds from the

Coastal Savannah and Guinea Savannah zones respectively. More infection occurred when the seeds from the three zones were dried to 8%oisture content than 10% moisture content.

Table 4.41 Effect of ambient room storage conditions on the survival of *Curvularia lunata* and *Aspergillus niger* on *Jatropha curcas* seed from the three zones

Seed Collection zone	Fungi					
	Curvularia lunata			*Aspergillus niger*		
	8% m.c.	10% m.c	Mean	8% m.c.	10% m.c	Mean
Coastal Sav. Zone	0.73	0.70	0.71	0.70	0.77	0.93
Forest Zone	0.70	0.70	0.70	1.06	0.91	0.98
Guinea Sav. Zone	0.70	1.07	0.38	0.94	0.73	0.73
Mean	0.71	0.82		0.90	0.80	
Lsd	zone = 0.06 m.c. = 0.07 zone x m.c. = 0.13			zone = 0.13 m.c. = 0.15 zone x m.c. = 0.27		
Cv%	12.8			20.4		

4.4.4 Survival of *Curvularia lunata* and *Aspergillus niger* on *Jatropha curcas* seed under six moths cold store conditions.

The infection levels of *Curvularia lunata* and *Aspergillus niger* under cold storage are indicated in Table 4.42. Seeds from the Guinea Savannah Zone dried to 8% moisture content were 139.4% significantly more infected than seeds from the Forest Zone dried to 8% and Coastal Savannah Zone dried to both 8% and 10% moisture levels ($p>0.05$). At 10% seed moisture content, forest Zone was 28.1% more infected than seeds from the Coastal Savannah Zone dried to both 8% and 10% moisture content. *Aspergillus niger* infection levels were observed not to be significantly different except when the seeds from the Guinea Savannah Zone were dried to 10% moisture content ($p>0.05$). Seeds from the three zones

were more infected when dried to 8% than at 10% moisture content. Cold storage promoted more of the fungi species infection than ambient room storage.

Table 4.42 Effect of cold store conditions on the survival of *Curvularia lunata* and *Aspergillus niger* on *Jatropha curcas* seed from the three zones

Seed Collection zone	Fungi					
	Curvularia lunata			*Aspergillus niger*		
	8% m.c.	10% m.c	Mean	8% m.c.	10% m.c	Mean
Coastal Sav. Zone	0.71	0.71	0.71	0.82	1.04	0.93
Forest Zone	0.71	0.91	0.81	1.06	0.91	0.98
Guinea Sav. Zone	1.70	1.07	1.38	0.94	0.73	0.83
Mean	1.06	0.77		0.94	0.89	
Lsd	zone = 0.06 m.c. = 0.07 zone x m.c. = 0.13			zone = 0.13 m.c. = 0.15 zone x m.c. = 0.27		
Cv%	12.8			20.4		

4.4.5 Survival of *Pennicillium sp.* and *Fusarium semitectum* on *Jatropha curcas* seed under six moths ambient room store conditions.

The infection levels of *Pennicillium sp.* and *Fusarium semitectum* are shown in Table 4.43. Seeds from the Guinea Savannah Zone dried to 10% moisture content recorded 78.5% and 34.4% significantly higher infection levels more than seeds from the Forest Zone dried to 10% moisture content and Coastal Savannah Zone dried to 8% moisture content respectively. Under ambient room storage conditions, *Fusarium semitectum* was not different among seeds from the three zones ($p>0.05$). At 10% moisture content, *Pennicillium sp*. infection level was higher than at 8% moisture content. On the contrary *Fusarium semitectum* was higher at 8%

moisture level. In addition, ambient room storage promoted the survival of *Pennicillium sp* and *Fusarium semitectum* than cold store conditions (Tables 4.43 and 4.44)

Table 4.43 Effect of ambient room storage conditions on the survival of *Pennicillium* sp. and *Fusarium semitectum* on *Jatropha curcas* seed from the three zones

Zone of seed collection	Fungi					
	Pennicillium sp.			*Fusarium semitectum*		
	8% m.c.	10%m.c.	Mean	8% m.c.	10%m.c.	Mean
Coastal Savannah Zone	0.93	1.07	2.00	0.73	0.70	0.71
Forest Zone	0.81	0.70	0.75	0.70	0.70	0.70
Guinea Savannah Zone	1.18	1.25	1.21	0.70	0.70	0.70
Mean	0.97	1.06		0.71	0.70	
Lsd	Zone = 0.13 m.c. = 0.15 zone x m.c. = 0.26			Zone = 0.04 m.c. = 0.04 Zone x m.c. = 0.08		
Cv%	21.5			8.0		

4.4.6 Survival of *Pennicillium sp.* and *Fusarium semitectum* on *Jatropha curcas* seed under six moths cold store conditions.

The infection levels of *Pennicillium sp.* and *Fusarium semitectum* are shown in Table 4.44. Seeds from the Guinea Savannah Zone dried to 10% moisture content recorded 28.5% significantly higher infection levels of *Fusarium semitectum* more than seeds from the Forest and Coastal Savannah Zones dried to both 8% and 10% moisture content. Under cold store conditions, *Pennicillium sp* was not different among seeds from the three zones ($p>0.05$). At

10% moisture content, both *Pennicillium sp*. and *Fusarium semitectum* infection levels were higher than at 8% moisture content.

Table 4.44 Effect of cold store conditions on the survival of *Pennicillium* sp. and *Fusarium semitectum* on *Jatropha curcas* seed from the three zones

Zone of seed collection	Fungi					
	Pennicillium sp.			*Fusarium semitectum*		
	8% m.c.	10%m.c.	Mean	8% m.c.	10%m.c.	Mean
Coastal Savannah Zone	0.73	0.79	0.76	0.70	0.70	0.70
Forest Zone	0.70	0.71	0.70	0.70	0.70	0.70
Guinea Savannah Zone	0.70	0.70	0.70	0.73	0.90	0.81
Mean	0.71	0.73		0.71	0.76	
Lsd	Zone = 0.13 m.c. = 0.15 zone x m.c. = 0.26			Zone = 0.04 m.c. = 0.04 Zone x m.c. = 0.08		
Cv%	21.5			8.0		

4.4.7 Survival of *Fusarium solani* and *Fusarium poae* on *Jatropha curcas* seed under six months ambient room store conditions.

Indicated in table 4.45 are the infection levels of *Fusarium solani* and *Fusarium poae*. Under ambient room storage conditions, *Fusarium solani* showed no differences in infection levels among the three zones except when the seeds from the Coastal Savannah Zone dried to 8% moisture content. On the other hand, *Fusarium poae* showed no differences among the seeds from three zones.

Table 4.45 Effect of ambient room storage conditions on the survival of *Fusarium solani* and *Fusarium poae* on *Jatropha curcas* seed from the three zones

Zone of seed collection	Fungi					
	Fusarium solani			*Fusarium poae*		
	8% m.c.	10%m.c.	Mean	8% m.c.	10%m.c.	Mean
Coastal Savannah Zone	0.73	0.70	0.71	0.70	0.70	0.70
Forest Zone	0.70	0.70	0.70	0.70	0.73	0.71
Guinea Savannah Zone	0.70	0.70	0.70	0.70	0.73	0.71
Mean	0.71	0.70		0.70	0.72	
Lsd	Zone = 0.02 m.c. = 0.02 zone x m.c. = 0.04			Zone = 0.04 m.c. = 0.05 Zone x m.c. = 0.09		
Cv%	4.1			9.3		

4.4.8 Survival of *Fusarium solani* and *Fusarium poae* on *Jatropha curcas* seed under six months cold store conditions.

The infection levels of *Fusarium solani* and *Fusarium poae* under cold store conditions are shown in Table 4.46. Variability exist among seeds from the three zones ($p>0.05$). *Fusarium solani* had similar infection levels on seeds from the Guinea Savannah Zone dried to 10% and Coastal Savannah Zone dried to 8% moisture levels. The rest did not differ irrespective of the zone from where the seeds were collected. *Fusarium poae* also showed differences only when the seeds from the Forest Zone were dried to 8% moisture content otherwise infection levels were not different among seeds from the three zones. Generally, cold store conditions promoted the survival of *Fusarium solani* and *Fusarium poae* than ambient room storage.

Table 4.46 Effect of cold store conditions on the survival of *Fusarium solani* and *Fusarium poae* on *Jatropha curcas* seed from the three zones

Zone of seed collection	Fungi					
	Fusarium solani			*Fusarium poae*		
	8% m.c.	10%m.c.	Mean	8% m.c.	10%m.c.	Mean
Coastal Savannah Zone	0.73	0.70	0.71	0.70	0.70	0.70
Forest Zone	0.70	0.70	0.70	0.87	0.70	0.78
Guinea Savannah Zone	0.70	0.77	0.70	0.70	0.70	0.71
Mean	0.71	0.72		0.75	0.70	
Lsd	Zone = 0.02 m.c. = 0.02 zone x m.c. = 0.04			Zone = 0.04 m.c. = 0.05 Zone x m.c. = 0.09		
Cv%	4.1			9.3		

4.4.9 *Cladosporium sphaerospermum, Fusarium moniliforme, Fusarium subglutinans, Myrothecium verucaria* and *Fusarium palledoroseum* survival on *Jatropha curcas* seed during six months of storage

The survival of *Cladosporium sphaerospermum, Fusarium moniliforme, F. palledoroseum, F. subglutinans* and *Myrothecium verucaria* are shown in Tables 4.48 to 4.51.

4.4.10 Survival of *Cladosporium sphaerospermum* and *Fusarium moniliforme* on *Jatropha curcas* seed under six months of ambient room store conditions.

Table 4.48 shows the infection levels of *Cladosporium sphaerospermum* and *Fusarium moniliforme* under ambient room store conditions. Seeds from the Forest Zone dried to 10% moisture content were 69.0% and 29.9% significantly more infected than seeds from the

Guinea Savannah Zone at both 8% and 10% moisture levels and the Coastal Savannah Zone dried to 10% moisture content ($p>0.05$). Seeds from Guinea Savannah and Coastal savannah Zones were not different except when the seeds from the latter zone were dried to 10% moisture content. *Fusarium moniliforme* did not show variability among the three zones except when the seeds from the Coastal Savannah Zone were dried to 10% moisture content. More infection occurred when the seeds from the three zones were dried to 10% compared with 8% moisture content.

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Table 4.47 Effect of ambient room store conditions on the survival of *Cladosporium sphaerospermum* and *Fusarium moniliforme* on *Jatropha curcas* seed from the three zones

Zone of seed collection	Fungi					
	Cladosporium sphaerospermum			*Fusarium moniliforme*		
	8%m.c.	10% m.c.	Mean	8%m.c.	10% m.c.	Mean
Coastal Savannah Zone	0.73	1.07	0.90	0.70	0.83	0.76
Forest Zone	0.73	1.39	1.04	0.70	0.70	0.70
Guinea Savannah	0.70	0.70	0.70	0.70	0.70	0.70
Mean	0.72	1.06		0.70	0.74	
Lsd	zone = 0.16 m.c. = 0.19 zone x m.c = 0.33			zone = 0.05 m.c. = 0.06 zone x m.c. = 0.10		
CV%	24.8			10.4		

4.4.11. Survival of *Cladosporium sphaerospermum,* and *Myrothecium verucaria* on *Jatropha curcas* seed under cold store conditions

Under cold storage, *Cladosporium sphaerospermum* and *Myrothecium verucaria* were significantly different (p>0.05, Table 4.48). *Cladosporium sphaerospermum* showed significance difference when the seed from the three zones were dried to 10% moisture content. *Myrothecium verucaria* infection level which did not differ under ambient storage conditions, only showed differences in infection when seed from the Forest Zone was dried to 8% moisture content in cold storage.

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Table 4.48 Effect of cold store conditions on the survival of *Cladosprium sphaerospermum* and *Myrothecium verucaria* on *Jatropha curcas* seed from the three zones

Zone of seed collection	Fungi					
	Cladosporium sphaerospermum			*Myrothecium verucaria*		
	8%m.c.	10% m.c.	Mean	8%m.c.	10% m.c.	Mean
Coastal Savannah Zone	0.76	1.18	0.97	0.70	0.70	0.70
Forest Zone	0.70	1.22	0.96	0.73	0.70	0.71
Guinea Savannah Zone	0.82	1.32	1.07	0.70	0.70	0.70
Mean	0.76	1.13		0.71	0.70	
Lsd	Zone = 0.16 m.c. = 0.19 zone x m.c. = 0.33			Zone = 0.01 m.c. = 0.01 zone x m.c. = 0.02		
Cv%	24.8			2.6		

4.4.12 Survival of *Fusarium palledoroseum* and *Fusarium subglutinans* on *Jatropha curcas* seed under six months ambient room store conditions.

The infection levels of *Fusarium palledoroseum* and *Fusarium subglutinans* are indicated in Table 4.51. There were no significant differences in infection levels of *Fusarium palledoroseum* among the zones except when the seeds from the Guinea Savannah zone dried to 10% moisture content. Also, the infection levels of *Fusarium subglutinans* only show differences when the seeds from the Coastal Savannah Zone dried to 10% compared with seeds from the other two zone at 8% and 10% moisture content. Under cold store conditions *Fusarium palledoroseum* and *Fusarium subglutinans* did not differ among the zones.

Table 4.49 Effect of ambient room store conditions on the survival of *Fusarium palledoroseum* and *Fusarium subglutinans* on *Jatropha curcas* seed from the three zones

Zone of seed collection	Fungi					
	Fusarium palledoroseum			*Fusarium subglutinans*		
	8%m.c.	10% m.c.	Mean	8%m.c.	10% m.c.	Mean
Coastal Savannah Zone	0.70	0.70	0.70	0.70	0.86	0.78
Forest Zone	0.70	0.70	0,70	0.70	0.70	0,70
Guinea Savannah Zone	0.70	1.11	0.70	0.70	0.70	0.70
Mean	0.70	0.83		0.70	0.75	
Lsd	zone = 0.09 m.c. = 0.11 zone x m.c. = 0.19			zone = 0.05 m.c.= 0.05 zone x m.c. = 0.10		
CV%	18.3			9.8		

CHAPTER FIVE

5.0 DISCUSSION

5.1 Assessment of the *Jatropha curcas* seed just after seed collection

Preliminary assessment of *Jatropha curcas* seed collected from the Coastal Savannah, Forest and Guinea Savannah Zones indicated that the fruit inherently contains three seeds per fruit/pod (Table 4.1). Seed development as well as number of seeds per fruit is genetically controlled (Driscoll, 1990; Tischner *et al.,* 2003). This was also observed by Heller (1996) and Ginwal *et al.,* (2004) who reported that *J. curcas* fruit is trilocular and contains three black seeds per fruit.

Environmental factors such as soil, temperature, sunshine and rainfall among others affect seed development and seed weight (Gardner *et al*., 1985). The seed weight observed in this study ranged between 572.1g and 702.3g. However, seeds from the Forest Zone weighed heavier than those from the Guinea and Coastal Savannah zones (Table 4.2). The observed differences in seed weight may be attributed to the variation in climate in the seed collection zones (Appendixes 3 to 5). The average weight observed in this study is however divergent from earlier observation by Henning (2004) and Benge (2006) who reported higher seed weight of 727g. This means that the seeds collected from plants growing in Ghana were generally lighter in weight.

This study also found that *J. curcas* seeds contain oil (Table 4.3) confirming similar findings by Tweneboah (2000). The seed oil content determined at harvest (at about 17.5% m.c.) indicated no statistically differences among the seeds of *Jatropha curcas* collected from the three zones ($p>0.05$). The seed oil content was high (50 % -52 %). This puts *Jatropha curcas* among the world oil seed crops as reported by Krishnakurthy (2005) who indicated that

Jatropha curcas seed contains high (30-40%) amount of oil. Seeds from the Forest Zone however contained higher oil content, followed by seeds from the Coastal Savannah and the Guinea Savannah Zone. High oil content from seeds from the Forest Zone could be due to the heavy seeds as reported by Kaushik *et al*., (2007). This was also reported by Tweneboah (2000) and Bankole *et al*. (2005) who observed direct correlation between kernel weight and seed oil content.

J.curcas seed exhibited epigeal type of germination (Gardner *et al*., 1985; Hadidi, 1996). Germination at harvest was high but did not differ ($p < 0.05$) among the three zones. This could be due to the fact that at physiological maturity seeds have high germination potential (Gardner *et al*., 1985). No statistical differences in germination meant that freshly harvested uninfected seed will germinate well irrespective of the zone of seed collection. Even though some fungi were found associated with the seed, germination was high. This means that the fungi might not have initiated any degenerative processes, such as metabolic activities which often cause degradation of seed quality including germination (Neergaard, 1979). Secondly, favourable soil moisture content regime provided as prescribed by ISTA (2007) might have contributed to the high germination and good seedlings development observed during the experiment. Hard seed coat of the *J. curcas* could also have impeded the entry of seed degrading fungi into the cotyledons and thus prevented seed deterioration (Cantliffe, 1998) and enhanced germination.

5.2 Assessment of the *Jatropha curcas* seed after drying

Seed oil content was significantly affected ($p>0.05$) when the seed of *J. curcas* was dried to 10% and 8% moisture levels (Table 4.3). From the results, seed oil content remained high (42% and 55%) and higher than those observed by Heller, (1996) who reported a range

between 36-40%. Seeds from the Guinea Savannah Zone dried to 10% and those from the Coastal Savannah Zone dried to 8% moisture, recorded comparatively lower values. Generally, oil content was higher when seeds from the three zones were dried to 10 % moisture level (Table 4.3), but lower values obtained seeds from the Guinea Savannah Zone were dried to 10% (reducing from 50.64% to 48.4%) and from the Coastal Savannah zone dried to 8% moisture contents (reducing from 52.53% to 42.65%), suggests that moisture content should be given serious considerations when drying *J. curcas* seeds from these two zones for high oil expression. The observed high oil content could be due to slow drying at low temperatures of the humidified dryer (Hatmann and Kester, 1990). When oilseeds are dried slowly at low temperatures, the seeds have extended shelf life and yet maintain the seed oil content (Daun, 1996; Satsry *et al*., 2007). Differences in moisture levels suitable for seed oil yield in *J. curcas* could be due to the storage conditions, packaging materials as reported by Simic *et al.,* (2007).

Seed germination was also found to be high ranging between 68% and 90% (Table 4.4) but these values were lower than those obtained before the seeds were dried (90% and 97%). The highest germination percentage was, observed in seeds from the Forest Zone which produced the highest seed oil content. This could be attributed to the fact that the seed was freshly harvested and was not degenerated by storage microflora (Neergaard, 1979). Germination percentage of seeds from the Guinea Savannah Zone and Coastal Savannah Zone were statistically the same ($p > 0.05$) but significantly lower than that from the Forest Zone. This could be attributed to drying effect and fungal infection Bankole *et al*., (2005) since some fungi were found associated with the seed.

Generally, germination percentage of the seeds from the three zones was higher at 10% moisture content. The higher germination percentage of seed from the Coastal Savannah Zone at 8% moisture content might be an isolated one since it was not statistically different from the germination percentage of seeds from the same zone at 10% moisture content (Table 4.4).

Higher mean germination percentage was exhibited by seeds from the Forest Zone dried to 10% seed moisture content (Table 4.4) despite the significant presence of *A. flavus, Collectotrichum dermatium*, *F. oxysporium* and *Cladosporium sphaerospermum* (Tables 4.13 to 4.16). This could be attributed to reduced seed moisture content that did not produce high relative humidity to cause deterioration. The experiment also showed that the drying temperature of about 40^{o}C of the *J. curcas* seed did not kill the fungi (Hartmann and Kester, 1990).

Seed vigour was determined by measuring vigour index and seedling dry weight (Tables 4.5 and 4.6). Seeds from the Forest Zone produced higher vigour index but lower seedlings dry weight. On the other hand, higher seedling dry weight was observed in seedlings from the Coastal Savannah and Guinea savannah Zones. The findings indicated that seeds from the Forest Zone have higher vigour index than seeds from the Coastal Savannah and Guinea Savannah Zones. However, higher seedling dry weight from the Coastal and Guinea Savannah Zones showed that the higher vigour index of seeds from the Forest Zone means that seedlings could easily be raised from the seeds from the latter two zones. It could however, be deduced from Figures 4.1 and 4.2 that seeds from the Forest zone have longer shelf life. Lower vigour index observed in the seeds from the Coastal Savannah and Guinea Savannah Zones may be due to fungi effect as reported by Cantlife, (1998).

Seedling growth parameters studied in this experiment varied significantly ($p>0.05$) due to seed drying. Seeds from the Forest Zone produced taller plants (Table 4.7), with longer petiole length (Table 4.10). Plants from seeds from the Guinea Savannah Zone produced more leaves but this was not statistically different from the leaf number of plants raised from seeds from the Forest Zone. This could be attributed to high seed vigour observed (Table 4.5) and less deteriorative effect of fungi associated with the seeds (Munster and Swendsen, 1987). This findings is similar to a report by Cantliffe (1998) that vigorous seeds germinated rapidly and produce normal seedlings within a wide range of environmental conditions.

Plants of seeds from the Coastal Savannah Zone showed superior performance in internode length, stem diameter, leaf number and leaf bud number over those from the other two zones (Tables 4.8 to 4.12). This means that plants raised from seeds from the Forest Zone channelled the photosynthates towards height and petiole development, whereas those from the Coastal Savannah and Guinea Savannah Zones utilized the photosynthates for internode length, stem diameter, leaf number and stem diameter development. The utilization of photosynthates for structural development and influenced by the environment was reported by Gardner *et al*., (1985). Growth parameters were higher for all parameters measured when the seeds were dried to 10% seed moisture level. This means that drying to 10% seed moisture could enhance plant development and thus must be considered when drying Jatropha seeds. Generally, the results indicated that *J. curcas* plants will establish easily irrespective of the seed source.

Ten fungal species were identified growing on the *J. curcas* seeds before storage indicating that *J. curcas* seed and fungi association possibly exist. This goes to support the report by the Adventist Development and Relief Agency - ADRA (2004) that some diseases prevented *J.*

curcas seed germination and hence affecting seedlings availability for field establishment. However, only four viz: *Aspergillus flavus, Collectotrichum dermatium, Fusarium oxysporium* and *Cladosporium sphaerospermum* differed significantly ($p<0.05$) among treatments (Tables 4.13 to 4.16). The infestation levels of the four fungi on seeds from the Forest Zone were observed to have higher infection levels of *Aspergillus flavus, Collectotrichum dermatium, Fusarium oxysporium* and *Cladosporium sphaerospermum*, than found on seeds from the Guinea Savannah and Coastal Savannah Zones. However, good seed germination and seedlings performance proves that the presence of fungi on the seeds does not necessarily result in disease condition in the field (Jindal and Thind, 1990). The four fungi species were found to maintain significant infection levels at 8% seed moisture content. Meaning 8% seed moisture might be favourable relative humidity for their development (FAO, 1981). The results further suggest that the drying temperature (about 40 ^{o}C) was not sufficiently high to kill these fungi (Hartmann and Kester, 1990).

5.3 Assessment of the *Jatropha curcas* seed during and after storage

Seed oil content differed significantly ($p>0.05$) after six months storage. The results showed that seed oil generally decreased after storage (Tables 4.17 and 4.18). Reduction in seed oil content at the end of the storage period may be attributed to the effect of the storage conditions, the seed moisture content and the fungi associated with the seed as found by Neergaard (1979) and Simic *et al*. (2007). Similar observations were made by Bankole *et al.* (2005) melon seed when they noted that the presence of *Aspergillus spp* decreased melon seed oil content quantitatively and quality in storage.

From the results, seed oil content decreased more in seeds from the Coastal Savannah Zone, followed by seeds from the Guinea Savannah Zone and the least reduction was from the

Forest Zone irrespective of the storage conditions. This means that the effects of both storage and fungi in reducing seed oil content was more intense in seeds from the Coastal Savannah and Guinea Savannah Zones than in seeds from the Forest Zone. The findings confirmed report by ADRA (2004) that poor storage couple with diseases affected *J. curcas* seeds germination. This also attests to Oladimeji and Kolapo (2007) who observed decrease in oil content of sunflower after a period of storage.

Generally, ambient room storage (Table 4.17) conditions (25^{o}C, 72% RH) preserved seed oil content better than when stored under cold (Table 4.17) conditions (10-15 ^{o}C, 90% RH). High relative humidity and cold storage provided congenial environment for the survival and destructive effect of the fungi as reported by Singh (1990) and Simic *et al.* (2007). This means fungi pathogens example hydrophytes and xyrophytes, were capable of causing deterioration of seeds at high and low levels of relative humidity respectively (Kwoseh, 1994). The experiment further indicated that freshly harvested seeds are more likely to be free from fungi infection and will express maximum seed oil as documented by Neergaard (1979).

The germination of *Jatropha curcas* seed was affected by the different moisture levels and storage conditions. Even though seed deterioration is inexorable (van Gastel *et al*., 1996), seed longevity is influenced by storage conditions and initial seed quality. Germination of *J. curcas* fell below figures obtained at harvest and after seed drying (Table 4.4). It is possible that the high seed oil content of *J. curcas* seed (Krishnankutty, 2005), the storage conditions and fungi associated with the seeds caused the reduction in germination over time as observed by Singh (1990).

Seedling dry weight which is an indictor of seed vigour and for that matter storability, showed a slight increase in the first month, followed by a dramatic increase in the third month and an equally sharp drop of vigour in the third month except seedlings dry weight of seeds from the Forest Zone which decreased in the fourth month (Figures 4.1 and 4.2). Thereafter, vigour decreased gradually for all seeds till the sixth month. The decrease in vigour over the period elicits the influence of the storage conditions and pathogenic degenerative effect of the fungi associated with the *Jatropha curcas* seed as reported by ADRA (2004), and Krishnankutty (2005). It also confirms the fact that seed naturally deteriorates in storage and lose value as regenerative material as reported by van Gastel *et al*., (1996).

A sharp decrease in seed vigour in the third and fourth months irrespective of the storage conditions confirms the fact that, loss of vigour is inherently inexorable and occurs faster and earlier than viability in seeds (van Gastel *et al*., 1996). In this experiment, the storage temperature and relative humidity were 10-15 ^{o}C / 90% for cold storage and 24-32 ^{o}C / 72-96% for ambient room storage. Similar findings by Kwoseh (1994) and Cantliffe (1998) indicate that high moisture and relative humidity in storage interact to reduce germination and seed vigour and will decrease faster at high temperatures. The experiment indicated that moisture proof containers under both cold and room storage at low seed moisture content improved *Jatropha curcas* germination and seed vigour as well as the velocity of germination (Tables 4.21 to 4.22) since the seeds were stored in white moisture proof containers. This agree with findings by George (1985) and Sinnadurai (1992) who stated that seeds are better stored in sealed containers at low temperatures. The pattern showed by the results implies that seeds from the Guinea Savannah and Coastal Savannah Zones had equally high initial seed vigour as that from the Forest Zone but shorter longevity (Figures 4.1 to 4.2). This is

because while vigour decreased in the third month for seeds from the Guinea and Coastal Savannah Zones, that for seeds from the Forest Zone decreased in the forth month. This means that seeds differ in longevity due initial seed quality and storage conditions (Simic *et al*. 2007).

Seedling establishment in pots in the field after storing the seed for six months showed that seedlings from seeds from the Forest Zone produced taller plants (Table 4.23 and 4.24), longer internodes when the seeds were stored in the cold store (Table 4.26) and plants with larger canopy when the seeds were stored under ambient room conditions. (Table 4.33). Since soil factors and moisture regime did not differ during the growth period, the superior performance of plants from seeds from the Forest Zone may be attributed to high light interception by the larger canopy (Gardner *et al*., 1985).

Plants raised from seeds from the Coastal Savannah Zone were superior in stem diameter, petiole length and leaf area index (Tables 4.27 - 4.28, 4.29 – 4.30 and 4.35-4.36) . However, these were not statistically different from values determined for plants from seeds from the Guinea Savannah Zone. With the exception of plant canopy spread, number of leaf buds (Tables 4.37 – 4.38) and number of leaves (Tables 4.31-4.32), most growth parameters measured expressed superior performance when the seed was dried to 10 % moisture content. This result showed that for better seedling growth *J. curcas* seed should be dried to at least 10 % seed moisture content before storage. The number of buds was more than the number of leaves and this that not all leaf buds developed into leaves and this also means that *J. curcas* plant has the propensity to developed blind buds. Again, it was observed that no branch developed during the ten-week growth of the plants. This implies that branching in *J. curcas* is delayed beyond ten weeks of growth.

Generally, growth performance of the *J. curcas* plant was superior before storage of seeds over those after storage. This may be attributed to favourable environmental factors such as soil moisture, temperature and light during the plant growth before seeds storage which occurred in the rain season. However, the seedling establishment of the plants after seed storage which occurred in the dry season was credible and suggests that *Jatropha curcas* seedlings could be raised in both seasons. The fungi did not produce any observable symptoms on the *J. curcas* seedlings in the field. This is not out of order since infection of seeds by seed-borne fungi does not necessarily result in diseased plants (Neergaard, 1979). This is contrary to report by (Maloy, 1993) who observed that *Aspergillus flavus* cause disease and eventual death of growing seedling from infected seeds.

Fifteen fungi species were detected on the *J.curcas* seed after six months of storage (Tables 4.39 to 4.49) by the Blotter Method as described by ISTA (2007). *Collectotrichum dermatium* though detected on the *J. curcas* seeds at harvest, was absent after storage under both ambient room and cold store conditions. This means that *Collectotrichum dermatium* might belong to the hydrophytes (Neergaard, 1979) since it could not survive the storage. Also ambient room conditions did not favour *F*. oxysporium (4.39) *C. lunata, A. niger* (Figure 441 to 4.42), and *Myrothecium verucaria* implying that these fungi species may belong to the mesophytes group (Neergaard, 1979; Hartmann and Kester, 1990). Higher infection levels of *A. flavus,* and *F. oxysporum* were found on seeds from the Forest Zone. This suggests high initial fungal infection of *J. curcas* seeds from the Forest Zone which persisted during storage.

The result also showed that seed moisture level affected fungi survival significantly ($p>0.05$). Out of the fifteen (15) species, *A. flavus* and *F. oxysporum* produced higher levels of infection at both 10% and 8% seed moisture levels (Figures 4.39and 4.40) under ambient

room and cold store conditions respectively. This means that *A. flavus* and *F. oxysporium* growth could probably be promoted by cool temperatures and high relative humidity (Neergaard, 1979). However, the dominant frequency of occurrence of *A. flavus* over *F. oxysporium* suggests a possible antagonistic effect exhibited by the former on the latter in storage as reported by Kwoseh (1994). The appearance of five more fungi species; *F. palledoroseum* (Figure 4.49), *Myrothecium verucaria* (4.48), *Rhyzopus sp, F. subglutinans* (Table 4.49), *and F. poae* (Table4.45 to 4.46) during seed storage could mean that both storage types provided conditions congenial for the development of theses fungi that resulted in their build-up.

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CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY

Jatropha curcas seeds collected from three major agroecological zones in Ghana were found to exhibit good seed qualities. Germination percentage, seed oil content and vigour were statistically the same when the fruits were harvested yellow-ripe. However, after seed drying and storage, seeds from the Forest Zone showed superior seed quality and seedlings performance in most of parameters measured. Both storage conditions maintained one or the other seed quality better, but cold storage promoted fungi survival. For germination to be maintained, seeds could be stored in the ambient room storage for at least six months. Seeds from the Forest Zone indicated higher propensity to store longer than seeds from the other two Zones. For the purpose of oil extraction, seed should preferably be stored in the cold store or extracted from yellow-ripe fruits.

6.2 CONCLUSION

Seeds from the three major ecological zones if well handled after harvest are good sources of seed. The experiment indicated that freshly harvested seeds or seeds extracted from yellow-ripe fruits are good for planting or oil extraction. Even though seed from the Forest Zone was superior in most of the parameters measured, seeds from the Guinea Savannah and Coastal Savannah Zones were also good as seed source for plant establishment. Cold storage promoted the survival of the fungi identified associated with the seed, but will be better option for storing *J. curcas* seeds for oil extraction. On the other hand, store under ambient room conditions to preserved seed germination.

6.3 RECOMMENDATION

1. Farmers should consider storing *J. curcas* seeds under ambient room conditions for six months because they would preserve germination and avoid cost involved in storing under cold store conditions.
2. Seed for oil extraction should be stored under cold store condition to preserve oil content if the volumes are too more to extract immediately after harvest.
3. The choice of seed moisture level (i.e. 10% or 8%) should be guided by the intended use of the seeds. For oil extraction, example, dry to 10% m.c.

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6.3.1 Further possible investigations

1. In the conduct of the experiment, some fungi were identified associated with the *Jatropha* curcas seed; it will therefore be expedient if an experiment is conducted to ascertain which treatment is best seed treatment against these fungi.
2. Harvest stage also needs to be identified for good seed quality since the experiment only restricted itself to seeds harvested at the yellow-ripe stage.
3. A detailed study on study on storage conditions needs also to be carried out to identify the exact and preferred conditions required to preserve the seed quality of Jatropha.
4. It may also be important to investigate whether the fungi identified are seed-born or seed-associated for efficient prevention and control.

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APPENDICES

1.0 SEED MOISTURE CONTENT AND STORAGE CONDITIONS.

Sample Source	**Moisture Content (%)**	**Storage Condition (^{o}C & RH)**
Guinea Savannah Zone	8	24 ^{o}C –32 ^{o}C and 72 %—96 % (Ambient Room)
Guinea Savannah Zone	10	--do--
Forest Zone	8	--do--
Forest Zone	10	--do--
Coastal Savannah Zone	8	--do--
Coastal Savannah Zone	10	--do--
Sample	Moisture Content (%)	10^{o}C –15 ^{o}C and 90 % (Cold)
Guinea Savannah Zone	8	--do--
Guinea Savannah Zone	10	--do--
Forest Zone	8	--do--
Forest Zone	10	--do--
Coastal Savannah Zone	8	--do--
Coastal Savannah Zone	10	--do--

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2.0 Average weather conditions during the trial period (March –October, 2007). at Hort Dep't.

Month	Temperature (^{o}C)		Relative Humidity (%)	Rainfall	
	Maximum	Minimum		No. of wet days	Amount (mm)
March	35.2	22.6	89	5	2.4
April	34.0	21.8	83	11	6.3
May	32.9	22.2	83	8	2.7
June	31.6	22.6	84	13	8.1
July	29.6	22.1	86	15	12.0
August	29.9	22.1	89	10	4.1
September	30.2	22.1	90	20	17.9
October	30.9	21.9	86	10	7.6

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3.0 Weather conditions during seed formation in the Coastal Savannah Zone: January, 2006 to February, 2007.

Month	Temperature (°C)		Relative Humidity (%)		Rainfall	
	Maximum	Minimum	Maximum	minimum	Sunshine Hrs	Amount (mm)
January, 2006	32.5	24.9	91	66	7.4	8. 7
February ,,	33.2	25.2	88	62	8.0	6.0
March ,,	33.2	24.9	88	62	7.3	25.8
April ,,	33.3	25.7	87	64	7.5	37.0
May ,,	31.5	24.1	92	70	7.1	236.6
June ,,	31.0	23.6	93	71	7.1	118.1
July ,,	29.4	23.6	90	71	4.9	42.1
August ,,	28.3	23.2	89	72	4.7	16.1
September ,,	29.5	23.4	91	71	5.7	71.1
October ,,	31.1	23.8	92	68	8.0	75.6
November ,,	42.4	24.8	90	64	8.4	11.2
December ,,	32.9	24.9	91	61	7.6	0.1
January, 2007	32.8	23.8	70	44	3.7	0.0
February ,,	32.8	25.6	89	62	7.2	17.4

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4.0 Weather conditions during seed formation in Forest Zone: January, 2006 to February, 2007.

Month	Temperature (°C)		Relative Humidity (%)		Sunshine	Rainfall
	Maximum	Minimum	Maximum	minimum	Hrs	Amount (mm)
January, 2006	32.6	21.2	87	57	6.3	109.7
February ,,	35.0	22.5	82	49	6.5	113.9
March ,,	32.9	21.8	82	58	6.3	91.4
April ,,	34.4	22.5	82	56	6.7	93.2
May ,,	32.2	22.0	84	64	6.4	143.9
June ,,	31.4	20.6	82	63	5.9	113.0
July ,,	30.3	20.8	86	69	3.8	68.0
August ,,	29.2	20.5	84	64	3.2	75.8
September ,,	30.1	21.1	88	69	3.1	96.8
October ,,	31.5	21.7	85	64	5.7	117.1
November ,,	32.3	21.8	82	53	7.7	60.2
December ,,	32.7	21.8	80	47	5.9	5.4
January, 2007	34.5	16.5	60	34	2.7	8.5
February ,,	34.0	22.4	83	49	5.9	65.3

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5.0 The season Weather conditions during seed formation in the guinea Savannah Zone:

January, 2006 to February, 2007.

Month	Temperature (°C)		Relative Humidity (%)		Sunshine	Rainfall
	Maximum	Minimum	Maximum	minimum	Hrs	Amount (mm)
January, 2006	-	-	-	-	TR	-
February ,,	38.5	24.1	-	-	8.09	22.9
March ,,	38.9	27.1	-	-	7.48	19.1
April ,,	38.2	27.5	-	-	8.23	58.5
May ,,	33.8	24.7	-	-	7.19	138.0
June ,,	32.3	23.7	-	-	7.50	87.9
July ,,	31.2	23.6	-	-	8.45	156.1
August ,,	30.4	23.2	-	-	5.70	211.2
September ,,	30.7	22.6	-	-	5.26	151.2
October ,,	33.2	23.0	-	-	8.32	124.3
November ,,	36.3	18.8	-	-	8.86	1.5
December ,,	36.0	16.8	-	-	8.41	0.0
January, 2007	34.9	18.4	-	-	6.12	0.0
February ,,	38.7	23.3	-	-	7.90	0.0

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