KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,
KUMASI, GHANA

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

ASSESSING THE EFFECT OF SEED QUALITY CHARACTERISTICS ON THE GROWTH AND YIELD OF FOUR COWPEA (*Vigna unguiculata* (L) Walp) VARIETIES

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI GHANA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE IN SEED SCIENCE AND TECHNOLOGY DEGREE

BY

NATALINE SONNIE BAYSAH

AUGUST, 2013

DECLARATION

I hereby declare that this submission is my own work towards the Master of Science (Seed Science and Technology), and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except for references where due acknowledgement has been given in the text.

NAME/DESIGNATION	SIGNATURE	DATE
Nataline Sonnie Baysah (STUDENT)	……..	……
Prof. (Mrs). N. S. Olympio (SUPERVISOR)	……..	……..
Dr. James Yaw Asibuo (CO-SUPERVISOR)	……	……..
Dr. Ben K. Banful (HEAD OF DEPARTMENT)	…….	……

DEDICATION

This work is dedicated to my dear Mother, Domorwah D. Jallah, who sent me to school, who consistently encouraged me and who motivated me to aim and reach the highest education. To my lovely son, Edward Kallon and the rest of the family members for their prayers and encouragement throughout the period.

ACKNOWLEDGEMENT

Glory and honour be to the King eternal, immortal and invisible God for His strength, enablement and sustenance throughout my entire education. Indeed, He is an awesome God and no one can fathom how he works.

I am very grateful to my supervisor, Prof. (Mrs.) N. S. Olympio at the Department of Horticulture for her guidance and tolerance in developing and completing this project. I am also highly indebted to my Co-supervisor Dr. James Y. Asibuo at the CSIR- Crops Research Institute for his directions and massive input throughout the project.

Without the financial assistance of Alliance for a Green Revolution in Africa (AGRA), my dream of attaining a Masters Degree would not have been materialized. I really appreciate your support and may the good Lord replenish your stock in hundred folds. I am also grateful to Prof. Richard Akromah, the Coordinator of the AGRA M.Sc Program in the Faculty of Agriculture, KNUST, for his directions and keeping me in check for timely completion of this project. I am also indebted to all the staffs of the Faculty of Agriculture for their useful and constructive suggestions. My appreciation is due to the Ministry of Agriculture – Liberia through CARI for granting me a study leave to carry out this programme. My appreciations to my sister Kebbeh Baysah Nyorkor and husband James S. Nyorkor for their tireless support and for taking care of my son during my education. I am also grateful to Pastor Tarnue Garmekollie and Mrs. Sarah Garmekollie for their constant prayers and encouragement. I want to thank my friend Ophelia K. Sallee and close relatives for their loving and cheerful support in the course of my study. I also wish to acknowledge fully the support of staff of the Legume section and Seed Pathology Section of the Crops Research Institute (CRI), Fumesua, Kumasi throughout this project. Lastly, I thank all my friends and loved ones who helped in diverse ways, I'am grateful to you all.

ABSTRACT

A study was conducted to investigate how the parameters of variety, seed size, seed health and some biochemical qualities of the seed affect the growth, yield and viability of the harvested cowpea seeds. Field and laboratory experiments were carried out from November 2012 to March 2013 at the Crops Research Institute of the Centre for Scientific and Industrial Research (CSIR-CRI) at Fumesua near Kumasi in the Ashanti Region of Ghana. Results of the study showed that there were no significant differences among varieties and seed size in terms of germinability for both original and harvested seeds. However, Nhyira large and Asontem small seed sizes had significant higher germination before planting. Nine (9) and ten (10) seed borne fungi were however, identified on the original and harvested seeds respectively, after conducting seed health test using the blotter method. On the effect of the incidences of seed-borne pathogens on seeds tested for germinability, a regression analysis showed that *Macrophomina phaseolina* and *Corynespora cassiicola* were predominant seedborne pathogens that had major effect on germination. The study also showed that plants from small seeded cowpeas emerged earlier when compared to large cowpea seeds. Small seed size of all the varieties emerged earlier when compared to large seed sizes of the same varieties. Higher seedling establishment was found in large cowpea seeds planted (95%) when compared to that of small seeds (88.6%). Plants from the large seeds were taller than plants from small seeds from 2 to 3 weeks after planting but did not have any advantage from week four up to the end of the growing period . Among varieties, Asontem had the highest height and Soronko recorded the least. There were no differences in pod and seed yields among varieties as well as in seed sizes. Large seeds planted produced larger seeds compared to small seed size. There were also no differences in proximate composition among varieties for original and harvested seeds. Large seed size had the higest proximate composition and that was significantly different from small seed size except for carbohydrate content which was high in small seeds than large seeds.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
AOSA	Association of Official Seed Analysts
CEC	Cation Exchange Capacity
CRI	Crops Research Institute
CSIR	Council for Scientific and Industrial Research
CV	Coefficient of Variation
DAP	Day After Planting
EC	Electrical Conductivity
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
IBPGR	International Board for Plant Genetic Resources
IITA	International Institute of Tropical Agriculture
ISTA	International Seed Testing Association
LS	Large Seed
LSD	Least Significant Difference
MoFA	Ministry of Food and Agriculture
MT	Metric Tonne
PROTA	Plant Resources of Tropical Africa
QDPI	Queensland Department of Primary Industries
RGR	Relative Growth Rate
SDW	Seedling Dry Weight
SGT	Standard Germination Test
SS	Small Seed

UCR	Utilized Cotyledonary Reserve
UNESCO	United Nation Educatioanal, Scientific, and Cultural Organization
USA	United States of America

CHAPTER ONE

1.0 INTRODUCTION

Cowpea *(Vigna unguiculata* (L) Walp) is a leguminous species native to Africa (Schippers, 2002). The crop is grown worldwide with an estimated production of over 5.4 million metric tonnes of dried grain, with Africa producing nearly 5.2 million metric tonnes. In Africa, Nigeria is the largest producer and consumer, accounting for 61% of total cowpea production in Africa and 58% worldwide. Africa exports and import negligible amounts of cowpea (IITA, 2009). West Africa is the key cowpea producing zone in Africa, mainly in the dry savanna and semi-arid agro-ecological zones. The principal cowpea producing countries are Nigeria, Niger, Senegal, Ghana, Mali and Burkina Faso (Langyintuo *et al*., 2003). An average of 143,000 MT is produced annually on about 156,000 ha of land in Ghana, making it the fifth highest producer of cowpea in Africa (TL II Project, 2012).

Cowpea exhibits different morphological forms; some are prostrate, erect or climbing. The leaves are trifoliate; inflorescences are axillary with few crowded flowers near the tip in alternate pairs. The anthers bear sticky and heavy pollen grains (Purseglove, 1984).

Cowpea is produced for household purposes and as a cash crop. It is a multipurpose crop, since it is cultivated for both leaf and seed yield (Schippers, 2002). It is also a multifunctional crop, providing food for man and livestock and serving as a valuable and dependable revenue-generating commodity for farmers and grain traders (Langyintuo *et al*., 2003). Cowpea is an important crop in Ghana due to its contribution to national

GDP, farmer incomes and food and nutrition security for the population (TL II Project, 2012). It forms a major component of the tropical farming system, because of its ability to improve marginal lands through nitrogen fixation and as a cover crop (Abayomi *et al.,* 2008). The crop fixes about 240 kg ha^{-1} of atmospheric nitrogen, and makes available about 60-70 kg ha^{-1} nitrogen for succeeding crops (Aikins and Afuakwa 2008). It is also a shade tolerant crop and, therefore, compatible as an intercrop with a number of cereals and root crops, as well as with cotton, sugarcane and several plantation crops. Coupled with these attributes, its quick growth and rapid ground cover has made cowpea an essential component of sustainable subsistence agriculture in marginal lands and drier regions of the tropics, where rainfall is scanty and soils are sandy with little organic matter (Singh *et al*., 1997).

Cowpea is a grain legume food crop that plays a critical role in the lives of millions of people in Africa and other parts of the developing world. It is a very important source of protein as well as carbohydrate in the diets of relatively poor people in developing countries (Elias *et al.,* 1964).

Cowpea faces numerous production constraints despite its importance. Cowpea farmers in the dry savanna areas of sub-Saharan Africa obtain low yields, estimated at about 350 kg per hectare (IITA, 2009) which is below its potential yield, 3,000 kg ha^{-1} (Rusoke and Rubaihago, 1994).

Seed size is an important physical indicator of seed quality that affects vegetative growth and is frequently related to yield, market grade factors and harvest efficiency (Rukavina

et al., 2002). According to Forbes and Watson (1992), seed size has a significant influence on the future performance of the seedling.

In addition, the presence of seed borne and seed transmitted pathogens on seeds is also one of the causes of low seed viability (Bewley and Black, 1994; Elias *et al.*, 2004). Many of the seed borne disease causing organism associated with cowpea, especially fungi reduce seed germination and produce symptoms on infected seedlings (Saad *et al.*, 1988). Infected seeds may fail to germinate, or transmit disease from seed to seedling and or from seedling to growing plant (Fakir *et al.*, 2002). It has also been demonstrated that seed-borne fungi are responsible for poor quality seeds in many crops (Neergaard, 1979). Among seed borne organisms, fungi cause maximum seed damage, which include reduced germination and vigour (Shetty, 1990).

The success of germination, seedling establishment and later growth and development of every agricultural crop depends on many factors. Among the various factors, seed quality is one of the most important to affect the success of crops (Finch-Savage, 1995). The use of high-quality and adapted seeds and planting materials exert the most profound influence on agricultural productivity. A wider appreciation of the importance of quality seeds and their crucial role in agriculture cannot be over-emphasized (Scowcroft and Polak Scowcroft 1998). Shetty (2000) indicated that good crop establishment is directly linked to the quality of seed used.

According to van Gastel *et al.* (1996), seed is the starting point of agriculture; it is a source of continuity, change, and restoration, as well as its most important product. The

seed contains the embryo as the new plant in miniature; it is structurally and physiologically equipped for its role as a dispersal unit and is well provided with food reserves to sustain the growing seedling until it establishes itself as a self-sufficient, autotrophic organism.

The most important prerequisite for good crop production is the availability of good quality seeds of high yielding varieties, adapted to the growing area, and preferred by farmers. Mew *et al.* (1994) reported that the quality of seeds alone is known to account for an increase in productivity of at least 5–20%.

Good seedling establishment and seedling vigor are essential for sustainable and profitable crop production and is therefore considered the most critical stage of a developing crop. This has a major impact upon many aspects of crop production that determine cost effectiveness and the inputs required, and also has direct influence on the yield and marketing quality of a crop (Finch-Savage, 1995).

Given the importance of quality seed, it is therefore essential that investigations are made to ascertain those factors that contribute to the poor germination of cowpea seeds and low yield in order to maintain the quality of the seeds and ensure their viability.

Earlier work on these quality characteristics indicates that they may influence the seedling establishment, yield, and even the quality of the harvested seeds (Guberac *et al.*, 1998; Larsen and Andreasen, 2004; Willenborg *et al.*, 2005). However, studies have been limited to cereals and some crops like pearl millet (Kawade *et al.*, 1987), safflower (Farhoudi and Motamedi, 2010), barley (Rukavina *et al.*, 2002) and some forage crops (Larsen and Andreasen, 2004). Besides, the reports vary on the actual effects of the

various sizes on germination, growth and yield of the different crops (Bremner *et al*., 1963; Wood *et al.*, 1977).

It will be important to establish the effect of seed size on cowpea due to its economic importance to Ghana and other West African countries.

The overall objective of the study was to determine how variety, seed size, seed health and some biochemical qualities of cowpea seed affect the growth, yield and viability of original cowpea samples as well as that of harvested seeds generated from the original seed samples.

The specific objectives of the study were:

I. To study the growth, yield and quality of four cowpea varieties
II. To evaluate the influence of seed size on growth and yield of the four varieties
III. To compare some seed biochemical qualities of original and harvested seeds of the four cowpea varieties
IV. To assess the seed health of the four varieties and their impact on the germination of original and harvested seeds.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Taxonomy of Cowpea

Cowpea (*Vigna unquiculata* L. Walp), an annual legume, is also commonly referred to as southern pea, blackeye pea, crowder pea, lubia, niebe, coupe or frijole. Cowpea originated in Africa and is widely grown in Africa, Latin America, and Southeast Asia and in the Southern United States. It is chiefly used as a grain crop, animal fodder or as a vegetable. The history of cowpea dates to ancient West African cereal farming, 5 to 6 thousand years ago, where it was closely associated with the cultivation of sorghum and pearl millet (Davis *et al.*, 1991). Cowpea is one of the world's dicotyledonous leguminous food crops and a major food crop of millions of people in the developing countries (Taiwo and Akinjogunla, 2006).

2.2 Morphology and Biology

Growth forms of the plant vary and may be erect, trailing, climbing or bushy, usually indeterminate under favorable conditions. Leaves are alternate and trifoliate usually dark green. The first pair of them is simple and opposite. Stems are straight, smooth or slightly hairy, sometimes tinged with purple (Aveling, 1999). Leaves exhibit considerable variation in size (6-16 x 4-11 cm) and shape (linear, haste, lanceolate to ovate) and they are usually dark green (IBPGR, 1983). The inflorescences are racemose or intermediate at the distal ends of 5-60 cm long peduncles. The flowers are borne in alternate pairs, with usually only two flowers per inflorescence. These are conspicuous, self-pollinating, borne on short pedicels and the corollas may be white, cream, pink, pale, blue, yellow or purple (IBPGR, 1983).

Flowers open in the early day and close at approximately midday. After blooming, they wilt and collapse. Fruits are pods that vary in size, shape, colour and texture. They are usually brown when ripe but may also be brown or purple in colour. There are usually 8-20 seeds per pod that vary in size, shape, color and texture. They are usually brown when ripe but may also be brown or purple in color. They may be erect, crescent-shaped, or coiled. Seeds are relatively large, 2-12 mm long and weigh 5-30g/100 seeds. The testa may be smooth or wrinkled, white, green, red, brown, black, speckled, blotched, eyed (the hilum central line is white surrounded by a dark ring) or mottled in color (Porter *et al.*, 1974). The seeds are variable in size and shape: kidney, ovoid, crowder, globose and rhomboid (IBPGR, 1983).

2.3 Uses and Nutritional Importance

Cowpea is a grain legume food crop that plays a critical role in the lives of millions of people in Africa and other parts of the developing world and is also a very important source of protein as well as carbohydrate in the diets of relatively poor people in developing countries (Elias *et al.*, 1964). The crop had been estimated to contribute more than half of the plant protein of human diets in the semi-humid tropics (Rachie, 1985). In fresh form, the young leaves and immature pods are used as vegetables, while the grain is used in the preparation of several dishes. Nutritionally, cowpea grain is rich in protein (20.5 - 31.7%), carbohydrates (56.0 - 65.7%); fat (1.1 - 3.0%), fiber (1.7 - 4.5%) and moisture (6.2 - 8.9%); (Onwuliri and Obu, 2002). According to Singh and Rachie (1985), cowpea contains small amounts of other nutrients such as folic acid, thiamine, riboflavin and niacin as well as some micronutrients such as iron and zinc. The

relative composition of carbohydrates and their richness in protein make them important components of the food ration of humans, particularly where there is insufficiency of proteins of animal origin, a typical situation in many tropical developing countries (Singh and Rachie, 1985). The seeds are, therefore, considered to be a suitable natural protein supplement to the stable diets of most people in Africa, which are based on either cereals such as maize, sorghum and rice or roots such as cassava (Bressani, 1985).

The stems, leaves, and vines serve as animal feed and are often stored for use during the dry season. Fifty-two percent (52%) of Africa's production is used for food, 13% as animal feed, 10% for seeds, 9% for other uses, and 16% is wasted (IITA, 2009).

It has been reported that folic acid, and vitamin B contents are found in higher quantity in cowpea compared to other plants and are necessary during pregnancy to prevent birth defect in the brain and spine (Timko and Singh, 2008).

Wide array of legumes are produced in Ghana, but cowpea is preferred on account of its short life cycle, fodder use and quality. The dry seeds may be boiled and eaten with "*Gari*" (a cassava product). It is also boiled together with rice and a colouring agent to give what is known as "*Waakye*". The boiled grains could also be served with fried ripe plantain (Quaye *et al.*, 2009). It is also used in preparation of weaning foods (Sefa-Dedeh, 2005). The roots of the cowpeas are eaten in Sudan and Ethiopia and the scorched seeds are occasionally used as a coffee substitute (Duke, 1981).

As a major source of protein, minerals, and vitamins in daily diets, it positively impacts on the health of women and children. The bulk of the diet of the rural and urban poor Africa consists of starchy food made from cassava, yam and plantain. Hence, the addition of even a small amount of cowpea ensures the nutritional balance of the diet and enhances the protein quality by the synergistic effect of high protein and high lysine from cowpea (Davis *et al*, 1991).

Cowpea can also be used as cover crop (Langyintuo *et al.*, 2003). The very early maturity characteristics of some cowpea varieties provide the first harvest earlier than most other crops during production period. This is an important component in hunger fighting strategy, especially in sub-Saharan Africa where the peasant farmers can experience food shortage a few months before the maturity of the new crop. Its drought tolerance, relatively early maturity and nitrogen fixation characteristics fit very well to the tropical soils where moisture, erosion and low soil fertility is the major limiting factor in crop production (Hall, 2004).

2.4. Production Status

2.4.1. Cowpea Production Systems

Traditionally in West and Central Africa, and Asia, cowpeas are grown on small farms often intercropped with cereals by the small scale farmers. Fertilizers and pesticides are generally not used, because they are too expensive or not available for the small farmers. In Western Africa; Burkina, Ghana, Mali, Niger and Nigeria both fodder and grain type varieties are grown sometimes as a pure crop and its commercial production is mostly done in these states. The cultivation of cowpea is mechanized in developed states like

Georgia, California, Texas, Mississippi, Arkansas and Tennessee in the USA (Fery, 1990).

2.4.2. Cowpea Production in Ghana

Cowpea is an important component of sustainable cropping system in Ghana. It is cultivated for the leaves, green pods, grain and haulm for livestock feed. Cowpea is an important source of vegetable protein and minerals for over 70% of Ghana population and it is the second most important grain legume. It is currently a food security crop (MoFA, 2010). Thus, rotating or intercropping cowpea with crops such as maize, sorghum, millet and cassava contributes to the improvement of soil fertility. The mean annual production of cowpea is 340 kg to 4000 kg. Sources of cowpea seeds for planting include market/traders, stored seed from own farm and from other farmers who preserve seeds for sale (MoFA, 2005).

2.5 Climatic and Soil Requirements

Cowpea grows primarily under humid conditions. It is tolerant to heat and drought conditions. The crop is sensitive to frost. It germinates rapidly at temperatures above 65^{o}F; colder temperatures slow germination (Davis *et al.*, 1991). Cowpea can be grown under rain fed conditions as well as by using irrigation or residual moisture along river or lake flood plains during the dry season, with the minimum and maximum temperatures between 28 and 30°C (night and day) during the growing season (Dugje *et al.*, 2009). Most of the crop grown in agro-ecological zones requires an annual rainfall ranging between 500 and 1200 mm. However, with the development of extra-early and early maturing cowpea varieties, the crop can thrive in the regions with an annual rainfall less than 500 mm. The crop requires well drained sandy loams where pH is in

the range of 5.5 to 6.5 (Davis *et al.*, 1991), however, it is tolerant of drought and well adapted to a wide range of soils, including sandy and even poor soils (Davis *et al.*, 1991).

2.6 Seed as a necessary input

The importance of seed to any crop-based production system cannot be overemphasized. It is the fundamental unit of any production system since it is the source of life. Improving the quality of seed of any preferred variety is the basis for agricultural productivity improvements (Louwaars and De Boef, 2012). In the past, human use of seed marks the evolution from nomadic food gathering to civilizations base on sedentary agriculture (Berg *et al*., 1991). Modern plant breeding and seed supply are just another stage in the same continuum of evolution and domestication (Chopra and Reusche, 1992). Characters of wild plants that were not suitable for agricultural crop production were selected against, while desirable characters were selected for. In this procedure, various plants have changed significantly and new types have developed (Berg *et al*., 1991).

The word 'seed' refers to any part of a plant that is used for reproduction, both generative (true seeds) and vegetative parts (Chopra and Reusche, 1992). Mayer and Polja, Kov-Mayber, (1989) indicated that seed in the precise botanical or broad horticultural sense are fertilized ovules containing embryos bounded by integument.

In Ghana and perhaps sub-Saharan Africa, seed is the most important production factor and perhaps the cheapest input for crop production (Niangado, 2010).

2.6.1. Seed Production Agronomy

Agronomic practices for seed production generally follow standard farming methods for the particular crop: proper land preparation, optimum plant spacing, soil fertility management and good weed control, disease and pest control (Louwaars, 1990). However, there are some general differences, between cultivation practices for certain crops (biennials, hybrids, woody plants and pasture crops), (QDPI, 1988). The main difference between grain production and seed production is the quality requirements of the latter (Kloppenburg, 1988).

2.7 Cowpea Production Constraints

2.7.1. Biotic Stress

2.7.1.1. Diseases

Cowpea is susceptible to a wide variety of pests and pathogens that attack the crop at all stages of growth (Allen, 1983), for instance cowpea wilt caused by *Fusarium oxysporium* f. sp. *lycopersici*, cowpea root rust caused by a nematode (*Meloidogyne ssp)* and cowpea bacterial blight caused by *Xanthomonas vignicola*. Losses due to pest attacks or diseases can be as high as 90% (IITA, 2000). For the parasites, *Striga gesnerioides* causes important yield losses which can be between 30% to 80% (Muleba *et al.*, 1997) and sometime the entire harvest (Obilana, 1987).

2.7.1.2. Insects

Some of the major insect pests of cowpea are pod borer (*Maruca vitrata*), flower thrips (*Megalurothrips sjostedti*), cowpea weevil (*Callosobruchus maculatus*), cowpea cuculus

(*Chalcodermus sermus*), and the southern cowpea weevil (*Mylabris quadrimaculatus*) (Fitter and Hay, 1987).

2.7.2. Abiotic Stress

The effects of the environment on plant growth may be divided into enforced damage effects (stress), caused by the environment, and adaptive responses, controlled by the plant (resistance), (Fitter and Hay, 1987). Damage, which may be manifested as death of all or part of the plant, or merely reduced growth rate due to physiological malfunction, is a common phenomenon and the agents are varied: temperature, water availability, soil chemistry, soil physical properties and others such as air pollution, wind and diseases. However, the most important environmental agents affecting plant growth in the semi-arid tropical zone is drought. Cowpea can also exhibit incomplete emergence when soil temperatures are below 19°C (Fitter and Hay, 1987).

2.8 The Concept of Seed Quality

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.

2.8.1 Seed size

Seed size (usually measured as mass) has long been regarded as an important aspect of plant reproductive biology. Traditionally, seed mass within a plant species is considered a remarkably constant characteristic (Harper *et al*., 1970; Silvertown, 1981). However, other studies have established that seed mass within a species or even an individual plant can vary greatly (Harper *et al*., 1970).

Differential seed size may have numerous important ecological implications. Differences in seed mass within a species may affect seed germination and germination rate (Weis, 1982; Zhang and Maun, 1990).

Big seeds often have greater percent germination or emergence than small seeds (Hendrix, 1984). On the other hand, small seeds may germinate more rapidly than large seeds and, thus, have a competitive advantage (Howell, 1981). Seed size also affects seedling biomass (Zimmerman and Weis, 1983).

Usually, the seedlings from big seeds are bigger than those from small seeds, especially in the early stages of growth (Saverimuttu and Westoby, 1996). The initial seedling size differences may persist until maturity (Weis, 1982) or become imperceptible with time (Zimmerman and Weis, 1983) because of the differential relative growth rate among seedlings from differently sized seeds (Zhang and Maun, 1990). Some studies (Zimmerman and Weis, 1983) indicate that a higher relative growth rate of seedlings

from small seeds exists only in the early stages of development, and or that the relative growth rate may be reduced in competitive conditions (Westoby *et al.*, 1996).

2.8.2 Effect of seed size on establishment

Optimum cowpea production relies upon a number of environmental and cultural parameters. Of these parameters, a rapid and uniform stand establishment is basic to vigorous seedlings and plant performance. Of the variables affecting stands establishment and plant performance, seed size is one trait that can easily be manipulated and may be of economic significance.

The basic tenets of these reports are;

(a) A bigger endosperm improves emergence ability.

(b) Bigger cotyledons are competent of higher photosynthetic rates.

The effect of seed size on germination and following seedling emergence have been investigated by many researchers in various crop species or cultivar (Guberac *et al.*, 1998; Larsen and Andreasen, 2004; Willenborg *et at.*, 2005). However, these results varied widely between species. Most investigators have reported a positive relationship between seedling vigor, improved stand establishment and higher productivity of cereal crops with plants originating from large seed compared to those grown from smaller seed. With increased seed size higher germination and emergence were determined in pearl millet (Kawade *et. al.*1987; Erskine, 1996), while seed size has no effect on germination of seeds in other reports (Main and Nafziger 1994; 1992), but besides higher germination percentage declined median germination time were determined in some forage plants (Larsen and Andreasen 2004). In safflower, there was no significant

difference between seed size on germination and for both seed sizes and all salinity treatments was greater than 90% (range 91-97%), Farhoudi and Motamedi (2010). Also in barley, germination was ranged 97.5% - 98.5% in four groups of seed sizes and there was no significant difference between them (Rukavina *et al*., 2002). Malcolm *et al*., (2003) noted that with increasing in seed weight and seed size of Peach rootstock increased the germination percent.

According to Harper and Obeid (1967), the depth of planting favours rapid germination of different size seeds at different depths; the greater embryonic capital associated with large seeds is advantageous only when they are buried deep in the soil, as small seeds may exhaust their reserves before reaching the surface.

Furthermore, Edwards and Hartwig (1971) in their study with groundnut on the effect of seed size upon rate of germination realized that the small seeded lines germinated more rapidly than the large seeded at each moisture level. Rapid germination in field plantings usually reduces the hazards of obtaining uniform stands. Taylor and Ten Broeck (1988) demonstrated that the amount of seedling emergence force expended increased linearly as seed size increased for an array of small- to large-seeded vegetable crops.

Bremner *et al*., (1963), however found that smaller seeds were more efficient in using reserve materials than larger ones. They concluded that the amount of reserve material available to the developing seedling is a dominant factor in the emergence force potential. They also showed that while embryo size had no significant effect on overall growth, endosperm size did. While this may be true for monocots, studies with carrot *(Daucus carrota* L.) seed indicated that mean emergence time decreased and percent

emergence increased with increased embryo length of heavier seeds (Gray and Steckel, 1983). Wood *et al.*, (1977) indicated that the use of large seed of a seed stock more often results in increase germination, speedier emergence, and improved seedling growth.

Marcos Filhol and Avancine, (1983) also indicated that comparisons within the same bean cultivar have shown that large seed had higher and faster germination and (Perin *et al.* , 2002) produced plants with increased shoot and root growth in the field. Stems were the plant organs mostly affected by seed size, as verified by Perin *et al.*, (2002).

Fehr and Probst (1971) observed that the inhibition of hypocotyls elongation might in part be magnified by increased soil resistance. The smaller the seed size, the less resistance to planting media during emergence. Bigger seed size has been linked with slower field emergence (Edwards and Hartwig, 1971).

However, adaptive interpretation of between species differences in seed weight, numerous excellent previous reviews summarized by Westoby *et al.* (1992) are based on the concept of a seed-number trade off, articulated graphically by Smith and Fretwell (1974). These propose that smaller seeds can be produced in larger numbers than bigger seeds from a given amount of material resources available for investment in progeny. Seed size consequently evolves as a compromise between these counter-posed selection pressures. More particularly the best compromised seed size is likely to depend on how much a seedling chances of establishing are enhanced by having more resources accessible to it, and thus relationship can be expected to depend on the environmental circumstances under which seedlings are establishing and on physiological and other attributes of the plant species (Foster, 1986). Seedling developing from small (less than

80 mg) or bigger (greater than 220 mg) seeds may have reduced vigour (Burris *et al.*, 1971). Within normal range of seed size, variety is more essential than seed size in determining emergence (Johnson and Leuders, 1974).

2.8.3 Effect of seed size on growth and yield

According to Mckensie and Tomes (1980), differences in seed size gave rise to differences in seed growth as bigger seeds give larger seedlings within seed lots of birds foot trefoil. There was however no reliable relationship between the seed size of diverse seed lots and the seedling produced, although lots containing a greater proportion of bigger seeds had better field emergence. Stanton (1985) found 6-fold differences in seed mass within a single seed pod. Large seeds were found to grow more rapidly and developed plants that produced more flowers than smaller seed. He concluded that reproductive fitness was influenced more by seed weight than emergence time. Tompkins (1965) studied the effects of seed size on maturity and yield of several broccoli cultivar transplants grown from large seed had significantly higher early yields than those from small seed. Baalbaki and Copeland (1997) reported that in wheat, seed size not only influence emergence and establishment but also affected yield components and ultimately grain yield.

Chaffai and Louhichi (2013) reported that seed size plays a major role in germination and establishment of vigorous seedlings that is essential to achieving high yield.

Seed size, both volume and density has been known as a factor in plant growth and development. Earlier experiment done by Kiesselbach and Helm (1957) resulted in a conclusion that seedling vigour was related to seed size. The more vigorous seedlings

continued to generate more vigorous plant as the season progressed except some ecological factor differentially affects the crop. Chastain *et al*. (1995) working on soft white winter wheat realized that, plants grown from bigger seeds were taller, heavier and had more tillers than plant grown from smaller seeds.

Gan *et al*. (2003) reported that the different chickpea cultivars may have different plant height, seed yield components and seed size distribution, but the size of seed planted had no significant impact on most of these parameters. The authors thus, postulated that seed size had no significant impact on plant growth, development and seed yield of large-seeded crops such as chickpeas (Gan *et al.,* (2003).

2.8.4 Seed Protein and Carbohydrate

Ries and Emerson (1973), while studying wheat seedling vigor, found protein content to be positively related to seed size. Seed lots with higher protein contents resulted in more vigorous seedlings and often higher yields. Similar studies have shown both high protein seeds and large seeds to be highly correlated with seedling dry weight at 20 days (Lowe *et al*., 1972)

(Lowe and Ries, 1972) hypothesize that the difference in endosperm protein content would give diverse levels of respiratory sub-state and amino acids for new protein creation. Hydrolysis occurring during germination would result in higher levels of amino acid in high protein seeds and could also induce increase enzyme activity. To further examine the protein factor, amino acids have been studied to monitor if any particular component is more essential than total protein content. Glutamic acid has been found to be positively related to seedling vigor (Lowe *et al*., 1972), however, protein content still

seems a better criterion for vigorous seed selection. Kale *et al*. (1998) however, reported positive association between seed mass and oil content in groundnut.

Use of the size-protein relationship as an aid in cultivar selection by plant breeders has been suggested by (Evans and Bhatt, 1977). They found that if size is uniform, differences in seedlig vigor are mostly genotypic. This could be used as a mass selection technique in teterogenous bulk populations. Houghton, (2006) Carbohydrates are the major food reserve found in seeds of most cultivated plants. The most common carbohydrate that serves as a nutritional reserve is starch, although hemicelluloses, amyloids, and raffinose oligosaccharides may also be important. The carbohydrates nourish the embryo plant until it breaks through the soil and can start making its own food through photosynthesis. In a dicot seed, such as a bean, two cotyledons fill most of the interior of the seed. The cotyledons, sometimes known as "seed leaves," are technically part of the embryo. They function as food storage and supply the developing embryo with nourishment until its own leaves become functional.

2.8.5 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), 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.

2.8.5.1 Seed as carriers of fungal pathogens

The term seedborne describes the state of any micro-organisms being carried with, on, or in the seed (Agarwal and Sinclair, 1997). Seed may either be infected or contaminated. Fungi may be classified as seed-borne or seed-transmitted according to the general terminology of pathogens: seed-borne fungi include all fungal types contaminating the surface of the seed or infecting its tissue. Seed-transmitted fungi cause no infection of the seed itself but only infect seedlings in the nursery or in the field (Neergaard, 1979). Saad *et al*. (1988) reported that many seed borne fungi on cowpea in India have been reported to reduce seed germination and produce symptoms on infected seedlings. An example of a seed-transmitted pathogenn is *Fusarium oxysporum;* casual agent of Fusarium wilt in cowpea (Mathur and Kongsdal, 2003). Symptoms include stunting of the affected cowpea plant, chlorosis, drooping, premature defoliation, withering of leaves and brownish purple discoloration of vascular tissues (Boyhan *et al.*, 1999). Transmission occurs through soil and seed (Singh *et al.*, 1997). *Colletotrichum dematium* (Pers.) has also been found to cause anthracnose in cowpea in South Africa, and the pathogen is widely distributed especially where the environment during the growing season is either dry or hot to slight humid (Smith and Aveling, 1997). *Macrophomina phaseolina* has been reported to be transmitted from seed to seedling of sunflower (Bhutta *et al*., 1996) and soybean (Anwar *et al*., 1995). *Macrophomina*

phaseolina (Tassi) Goid causes an economically important disease of cowpeas and beans, known as ashy stem blight or charcoal rot De Mooy and Burke, (1990). In Uganda, Nakawuka (1996) reported reduced germination of up to 40% in untreated seeds that was attributed to seed-borne pathogens while Nabakka, (1997) reported germination reduction of up to 59.3% as a result of *Macrophomina phaseolina* infection in cowpea seeds; while *Cercospora canescens* and *Cercospora cruenta* both cause Cercospora leaf spot on cowpeas (Williams, 1975). They can cause considerable leaf spotting of cowpea after flowering (Singh and Allen, 1979). *Corynespora cassiicola* is an anamorphic fungus, which causes foliar spots in more than 70 species of plants worldwide (Silva *et al.*, 1998). In Northern Brazil, *Corynespora cassiicola* is considered to be one of the worst pathogens of tomato (Kurozawa and Pavan, 2006). It has been reported that *Phoma exiqua* is the casual agent of ascochyta blight in beans in Kenya, Rwanda, Zambia and Zaire; and it infection is favored by high humidity, cool, winds and moderate temperature Boerema (1982). According to (Tarr, 1972), there are many host and environmental factors which directly or indirectly affect the transmission rates of seedborne pathogens. Temperature, moisture, light and pH are the most important environmental factors which influence the infection of plants.

The vast majority of seed-borne fungi are harmless saprophytes; only a small number are seed transmitted or seed pathogens (Halloin 1986). *Aspergillus flavus* and *Apergillus niger* and some *Penicillium* species however, they are associated with damaged seeds. Agarwal and Sinclair (1995) regard these fungi as "storage fungi" that can be involved in deterioration during storage. The storage fungi, mainly comprising several species of *Aspergillus spp, Penicillium spp, Cladosporium spp., Curvularia spp., Rhizopus spp.* do

not invade grains to any appreciable degree or extent before harvest (CABI, 1996), but they can cause severe discolouration of seed in storage resulting in germination failure, discoloured or otherwise damaged embryos or whole seeds, and production of mycotoxins that constitute a health hazard for man and animals (Dharam Vir, 1974)

Diekman (1996) reported that any part of the plant is subject to disease, which may occur at any stage: seed, seedling, growing plants etc. However, Agarwal (1995) reported that seed borne microflora association with seed does not necessarily result in disease condition but may rather enhance seed protection. Maude, (1996) reported that seed high in purity and germination but infected with seed-borne pathogens is of low planting value. Planting seed that is free of seed-borne pathogens is the primary means of limiting the introduction of pathogens, especially new pathogens, into a field. Planting infected seed may also result in widespread distribution of disease within the crop, and could allow for an increased number of initial infection sites early from which the disease can spread (Wright and Tyler, 1994). The consequences of planting infected seed depend on the pathogen in question. For those diseases that are primarily soil or residue-borne, planting infected seed is less important. According to Machado (1988), damage could be caused by seed-borne pathogens which may be directly related to their inoculums potential in the seed locus where fungal penetration takes place. The extent of their damage depends also on seed physiological quality. These damages could affect germination. However the higher the seed vigor, the more resistant it is to fungal penetration and their reaction to affect germination (Mycock and Berjak, 1995)

Effects of seed-borne fungi on plant health vary widely. Seed-borne pathogenic fungi may survive for long periods in storage and may attack seedlings during germination leading to poor emergence and a reduced seedling population. Pathogens may also be transmitted from the seed to the seedling causing disease symptoms and possible yield loss at a later stage of growth. Some seed borne diseases can multiply rapidly from one generation to the next and seed crops can also become infected from neighbouring diseased crops.

In this way seed-borne disease can seriously affect the quality of both certified and farmer-saved seed (Wright *et al.,* 1995). Seed-borne pathogens may result in loss in germination, discoloration and shriveling (Wright *et al.,* 1995). Earlier, Neergaard (1979) also pointed out that seed can serve as a vehicle for the dissemination of plant pathogens when they bear inoculums, which can result in disease outbreak through infection in the endosperm or embryo. There is awareness that the increasing movement of seed germplasm around the world also provides an avenue for the dispersion of crop pathogens (Hampton and Tekrony, 1995).

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

2.8.6 Seed health testing

Seed health is a measure of freedom of seeds from pathogens. The presence or absence of seed-borne pathogens can be confirmed through the use of seed health testing

(Agrawal, 1995). It includes visual examination of seeds externally or internally, macro or microscopically for the presence of pathogens as well as incubating seeds on agar or moist blotter papers and identifying the pathogens microscopically (Warham, *et al*., 1990). It has been reported that the blotter test gives an indication of the infection of the seed, as shown by the presence of mycelium and fruiting bodies, and, in some tests, infection of the germinated seedlings as demonstrated by symptoms on the young plants ISTA (1993).

2.8.7 Germination

According to Hadidi (1996), germination is the resumption of active growth of the embryo initiated when the seed is subjected to favorable 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 favorable conditions in soil (Mathur and Kongsdal, 2003). Germination has been defined as an indication of a seed's ability to produce a normal plant under favorable conditions AOSA (2002). However, field conditions are rarely optimal and the germination rate may at times over estimate field emergence and seedling survival (AOSA, 2002). Those differences in field performance are often attributed to the physiological quality component known as seed vigour (Spears *et al*., 2002).

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: mathematical values based on standard laboratory test results, germination under stressful condition and biochemical testing.

The ultimate objective of testing for germination is to gain information with respect to the field planting value of the seed (ISTA, 1985). Field emergence ability is the major aspect of seed quality of concern to growers (Pieta-Filho and Ellis, 1991). The second objective of germination test is to provide results which can be used to compare the values of different seed lots (ISTA, 1985). Germination test result in conjunction with the analytical purity result provides the principal data upon which the seed traders buys, markets and sells seeds nationally and internationally (Hampton and Coolbear, 1990).

The third objective of germination test pertains to storage. The initial quality of seed determines its potential longevity under storage conditions (Roberts and Ellis, 1989). Germination testing and seed moisture content is traditionally used to provide the data upon which storage decision is based. Thus, a seed store manager would correctly conclude that a seed lot with germination of 95% should be able to be stored longer under the same conditions of temperature and humidity than a seed lot of the same species and cultivar with a germination of 75% (Hampton, 1990).

Basu (1990) reported that it is difficult to maintain germination capacity or the potential viability of seed especially in hot climates but acknowledged that germination results remain the prerequisite for assessing seed for planting or industrial purposes.

2.8.8 Seed Vigour

Seed vigour can be defined as (a) 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), (b) the ability of the seed to germinate rapidly and produce normal seedling under a wide range of conditions Cantliffe (1998). Due to variations in vigour, seed lots with similar germination may

respond differently when subjected to adverse field conditions. 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). 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.

According to (Perry, 1981), seed vigor is a concept rather than a specific property of a seed or seed lot, and that several factors like; genetic constitution, environment and nutrition of mother plant, maturity at harvest, seed weight and size, mechanical integrity, deterioration and ageing and pathogens are known to influence seed vigor. Therefore, care has to be exercised in selecting a seed vigor test to do the job. Two criteria have been employed by the ISTA seed vigor committee to evaluate, the performance of seed vigor test methods for different crops. The two criteria are reproducibility of vigor method and the relationship between vigor test results and seedling emergence in field soil. There is no universally accepted vigor test for all kinds of seeds Perry (1984). In a study on soybean seeds comparing electrical conductivity among genotypes, Kuo (1989) observed the existence of variability in seed coat permeability; thus, he concluded that this is a test that can be employed in genetic improvement programs aiming at the

enhancement of physiological seed quality. The EC values of soybean seeds are also influenced by the degree of hardness of the genotype Kuo (1989).

Generally, vigor tests have proven to be more useful as predictors of field emergence than the standard germination test. When planted in fields with stressed environmental conditions, especially cool, wet conditions, a high vigor seed lot can withstand the stress during germination and early seedling development longer than a low vigor seed lot (Spears *et al*., 2002). Thus, emergence is generally higher and seedling growth is more rapid.

Vigor tests are used extensively in the seed industry to provide a sensitive, consistent, fast, simple and economic method that can be used to predict the seed performance in the field environment McDonald (1980).

CHAPTER THREE

3.0 MATERIALS AND METHODS

The studies were conducted to assess the effect of seed quality characteristics on the growth and yield of four cowpea varieties. This was done in two phases which included laboratory analyses for seed quality characteristics and a field experiment.

3.1 Source of seeds

Seeds of four improved cowpea genotypes harvested between November 2011 and March 2012, were obtained from Crops Research Institute of the Centre for Scientific and Industrial Research (CSIR-CRI). The four varieties were Asontem, Nhyira, Soronko and Tona.

3.2 Sample size

One kilo gram (1kg) of the pure seeds of each variety was used for the investigations.

3.3 Laboratory Analysis for Seed Quality Characteristics

The laboratory tests conducted were: seed size sorting, thousand seeds weight, moisture content, standard germination test (SGT), seedling dry weight (SDW), electrical conductivity (EC), oil content, protein content, fiber content, carbohydrate content and seed health test. The laboratory investigations were conducted before sowing for size sorted seeds except for seed health test. Laboratory analysis for harvested seed was conducted without sorting. Seed sorting and weighing and seed health test were conducted at CRI seed pathology laboratory. Germination was done at the Department of Horticulture while the conductivity and nutrients analyses were conducted at the Soil

and Crop Science Laboratory at the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology in Kumasi.

3.3.1 Seed size sorting

The samples were manually sorted into two seed sizes (big and small) by length, width and thousand seed weight. Large seeds ranged from 7.69-8.15mm in length, 6.17-6.40mm in width and 133-148 g in 1000-seed weight. Small seed ranged between 5.10-6.42mm in length, 4.20-4.95mm in width and 1000-seed weight of 94-110g. Treatments used were eight: (1) Asontem large seed size; (2) Asontem small seed size; (3) Nhyira large seed size; (4) Nhyira small seed size; (5) Tona large seed size; (6) Tona small seed size; (7) Soronko large seed size and (8) Soronko small seed size.

The seeds were separated by their size from the same stock, based on seed length and width following the procedure described by Demooy and Demooy (1990). Ten randomly selected seeds were used for measuring each of the dimensions in triplicates with Venier calipers.

3.3.2 1000 Seed weight (g)

1000 Seed weight was determined by randomly counting hundred seeds in replicates of eight, weighed and recorded in grams. The mean weight was then multiplied by ten to obtain the thousand seed weight as per the procedure given under ISTA Rules (ISTA, 1996).

3.3.3 Moisture Content

The moisture content was determined using oven dry method according to International Rules for Seed Testing (ISTA, 1985). Five grams (5g) of ground seeds were placed into

small aluminum containers which was weighed and placed into the oven at 130 °C for 1hour. The moisture content was calculated using the formula:

$$Mc = \frac{b - c}{b - a} \; X \; 100$$

Where a is the weight of container

b is the weight of container and ground seed

c is the weight of container plus ground seed after drying

3.3.4 Germination Test

Germination test consisted the sowing of 100 seeds in four replicates using sterilized river sand. The sand was sieved using 0.4mm mesh as recommended in ISTA Rules (a range of 0.8mm to 0.05mm) and readily sterilized by heat at 150°C for 1h. Sterilized sand was filled in each of the plastic containers with volumes of (13.2) litres which had 5 holes perforated at the base to drain excess water. Seedling counts were made on the 5th day to serve as vigor indicators of the various samples. Final counting was recorded on the 8th days after planting and total percent germination determined as recommended by ISTA (2007).

$$Germination\% = \frac{number\ of\ germinated\ seeds}{number\ of\ total\ seeds\ planted} \; X \; 100$$

3.3.5 Seed Vigour Test

According to ISTA (2005), seed vigour is the sum of those properties that determine the activity and performance of seed lots of acceptable germination in a wide range of environments. Thus, vigorous seed lot should perform well even if the environmental conditions are not optimal for growth of that specific species. The vigour of two seed sizes of four cowpea genotypes was determined using seedling dried weight (SDW) (Perry, 1981). Twenty five (25) seedlings from each replication of the 8 samples were selected at random. Each sample was enveloped and oven dried at 80°C for 24 hours. Afterwards, the dried samples were cooled and weighed using analytical balance. The recorded weight was divided by the number of seedlings (25) to obtain the seedling dried weight. The vigor was then calculated by multiplying the seedling dried weight by germination percentage of each replication as indicated by Perry (1981).

Vigour = germination % x seedling dried weight

3.3.6 Conductivity test

Conductivity test is used to determine seed quality with regards to vigour and seed coat integrity. Conductivity test is based on the premise that as seed deterioration progresses, the cell membranes become less rigid and more water-permeable, allowing the cell contents to escape into solution with the water and increasing its electrical conductivity (ISTA, 2007). The test gives an accurate estimation of membrane permeability. Seed lots having high electrolyte leakage, that is, having high leachate conductivity, are considered as having low vigour, whilst those with low leakage (low conductivity) are considered high vigour (ISTA, 2007).

Electrical conductivity was determined using 4 replicates of 50 weighed seeds for each treatment. The seeds were seeped for 24 hours at a temperature of 20 °C in 250ml flasks containing sterile distilled water and two control flasks with each test run containing only sterilized distilled water. After this period the flasks were swirled for 10-15 sec and seeds were then taken out of the water with a clean forceps. An electrical conductivity meter was used to measure seed conductivity by inserting the conductivity dip cell into the seeped water until a stabilized reading was achieved and recorded. The conductivity dip cell was rinsed once in each of two beakers of rinse water between each sample measurement. The mean of the two control flasks (sterilized distilled water) when measured served as background reading (5) (ISTA, 2007). Conductivity was calculated using the formula;

$$\boldsymbol{Conductivity}\ (\boldsymbol{\mu s/cm^{-1}g^{-1}}) = \frac{\boldsymbol{Conductivity\ reading(\mu s/cm^{-1}) - background\ reading}}{\boldsymbol{Weight\ (g)\ of\ replicate}}$$

3.3.7 Protein Content Determination

The protein content was determined by the Kjeldahl method in three steps: digestion, neutralization and distillation, and titration.

Digestion: About 2g of the sample (ground seeds) was weighed into a digestion flask and mixed with 25mL concentrated H_2SO_4, selenium catalyst and few anti-bumping agents. The flask and its content were digested by heating in a fume chamber till the colour of the solution turned clear.

Neutralization and Distillation: After the digestion was completed the digestion flask was allowed to cool and the solution transferred into a 100mL volumetric flask and the volume made up to the 100mL mark with distilled water. The distillation apparatus was flashed out with water and 10mL of digested sample transferred into the distillation apparatus. The solution was then neutralized with 18mL NaOH and boiled under distillation water in a steam generator.

Circulation was allowed for about 10 minutes. A conical flask was filled with 25mL of 2% boric acid and 3 drops of mixed indicator (methylene blue and methylene red) added. The conical flask and its content were placed under the condenser in a position where the tip of the condenser was completely immersed in solution for 10minutes and end of condenser washed with distilled water (AOAC, 1995).

Titration: The nitrogen content was estimated by titrating the ammonium borate formed in the conical flask with 0.1M HCl solution. Titre values of the replicate samples were recorded and percentage nitrogen calculated as shown below. A blank sample was run at the same time as the sample was being analyzed.

Calculation of crude protein content

$$\%Nitrogen = \frac{(S_t - S_b)\mathbf{100}\ X\ \mathbf{0.1}\ X\ \mathbf{0.014}\ X\ \mathbf{100}}{Sample\ weight\ X\ \mathbf{10}}$$

S_t= Titre of sample

S_b= Titre of blank

Percentage nitrogen (%N) was converted to percent crude protein by multiplying by a factor of 6.25 (%Protein = % N x 6.25) (AOAC, 1995).

3.3.8 Crude Fat/Oil Content Determination

The crude fat content was extracted with petroleum ether using Automatic Soxhlet apparatus. Two grams of each sample (milled) was put in filter paper and folded properly. A second filter paper was wrapped around it and a piece of cotton wool was placed at the top to evenly distribute the solvent as it drops on the sample during extraction. The sample packet was placed in the butt tube of the soxhlet extraction apparatus. The extraction flask was placed in an oven at 103^{o}C for about 5 minutes, then cooled and weighed. The extraction continued with petroleum ether for 2-3 hours without interruption by gently heating, allowed cooling and then dismantled the extraction flask. The ether was evaporated using water bath until there was no odour on the ether remaining. It was then cooled at room temperature and the extraction flask was reweighed (AOAC, 1995). Fat percentage was determined by (weight differences).

Calculation of cowpea seeds fat content:

$$\%Fat = \frac{weight\ of\ fat}{weight\ of\ sample}\ X\ 100$$

3.3.9 Crude Fibre Determination

Crude fibre was determined using the method of AOAC (1990) (method14:020). About 2.0g of the cowpea sample was hydrolyzed in a beaker with petroleum ether after which it was boiled under reflex for 30 min with 200ml of a solution containing 1.25% H2SO4

per 100ml of solution. The solution was filtered through a filter paper onto a fluted funnel. After filtration, the samples were washed with boiled water until they were no longer acidic. Then, the residue was transferred onto a beaker and boiled for another 30min with 200ml of solution containing 1.25 % NaOH per 100ml. The boiled samples were washed with boiled distilled water. The residues were filtered through Gooch filter crucible, dried at 1000 ^{o}C for 2 hours in an oven, cooled and washed. The percentage crude fibre in the cowpea sample was calculated as per the formula:

$$\%\boldsymbol{Crude\ fiber} = \frac{\boldsymbol{weight\ after\ drying}}{\boldsymbol{weight\ of\ sample}}\ \boldsymbol{X\ 100}$$

3.3.10 Carbohydrate Determination

The total percentage carbohydrate content was determined by the difference method as reported by Onyeike *et al*., (1995). This method involved adding the total values of crude protein, crude fibre, moisture and ash constituents of the sample and subtracting it from 100. The value obtained is the percentage carbohydrate constituent of the sample.

Thus: % carbohydrate=100–(% moisture + % crude fibre +% protein+%lipid+% ash).

3.3.11 Seed Health Test

Seed borne fungi were detected using the blotter test method.

Ten seeds were randomly selected from a well-mixed working sample of 400 seeds from each of the eight samples using the hand halving method (Mathur and Kongsdal, 2000). The 10 seeds were plated equidistantly on Petri dishes lined with 3 layers of water-soaked filter papers and each seed lot was replicated four times. The samples were then incubated for seven days under 12 hours alternating cycles of near ultra violet (NUV)

light and darkness at 20 ^{o}C to stimulate fungal sporulation. Fungi were identified with reference to growth characters using a stereomicroscope and compound microscope. In cases where fungi could not be identified through the stereomicroscope, slides of fruiting structures mainly conidia were prepared and examined under the compound microscope at magnifications objective lens with the help of seed health technicians. Structures observed were compared to those in the Common Laboratory Seed Health Testing Manual for confirmation and recorded (Mathur and Kongsdal, 2000).

3.4 Description of Study Area for Field trial

The Field experiment was carried out at the Research fields of CSIR-Crops Research Institute at Fumesua, Kumasi Ghana, during the dry season (November 2012 to February 2013). Fumesua is in the semi-deciduous forest zone with elevation of 186m above sea level (ASL) and has a bimodal rainfall distribution. The soil at the experimental site at Fumesua is Asuansi series, a ferric Acrisol (FAO/UNESCO legend, 1986). The main temperature during the experiment was 24.1^{o}C, 73% relative humidity and rainfall of 1.20 mm (KNUST Agricultural Engineering Department 2012/2013).

3.4.1 Cropping History of Study Area

The experiment was conducted in plots that had previously been planted to groundnut.

3.4.2 Soil Sampling and Analysis

Soil samples were taken from different locations of the field which was used for analysis. The soil was taken at 0-15cm depth. Among the various properties that were analyzed include pH, total nitrogen, available phosphorus, exchangeable ions and organic matter (Appendix A).

3.5 Experimental Design and Cultural Practices for field study

The experimental area was ploughed to a depth of about 20 cm and harrowed, and treatments were assigned to the plots. The experimental design was 4x2 factorial laid out in Randomized Complete Block Design (RCBD) with three replications. Each experimental plot measured 18 m^2 (5mx3.6m) and plants were spaced 60 cm between rows and 20 cm within rows (Appendix B). A total of 24 plots were used and each plot consisted of six rows with 50 plants per row. At planting, three seeds were sown and thinned to two plants per hill at two weeks after emergence to give a final plant population density of 7200 plants. Weeds were controlled by hand hoeing at week two (2) and five (5) after planting and thereafter as and when necessary.

3.6 Field Data Collection

3.6.1 Crop Growth Parameters

Vegetative growth was assessed by measuring the following parameters:

3.6.1.1 Field Emergence

Field emergence was assessed by counting from the first day plants emerged till the day 50% of the plants emerged. The two middle rows were used for the data collection and the outcome was expressed as a percentage of the total expected from the two rows.

3.6.1.2 Plant Height

Plant height was measured on five tagged plants with a meter ruler of each plot. This measurement was taken weekly from the ground level to the highest leaf axils of the main stem.

3.6.1.3 Number of Branches per Plant

The number of branches was determined by counting the number of branches on the same five tagged plants in the two middle rows on a weekly basis from three weeks after planting.

3.6.1.4 Shoot Fresh Weight

This was determined by cutting five plants at ground level from the 2nd and 5th rows of each plot for destructive sampling at 2, 3, 4, 5, and 6 weeks after planting. Fresh weights were measured using an electronic scale. Mean fresh weight per plant was recorded in grams

3.6.1.5 Shoot Dry Weight

This was determined by cutting five plants at ground level from the 2nd and 5th rows of each plot for destructive sampling at 2, 3, 4, 5, and 6 weeks after planting. Plants were oven dried at 80^0C for 48 hours and the dry weights were measured using an electronic scale. Mean dry weight per plant was recorded in grams.

3.6.2 Yield Parameters

3.6.2.1 Number of Pods per Plant

This parameter was estimated at harvest by counting the number of pods on the five tagged plants from the two middle rows and the mean was recorded.

3.6.2.2 Pod Length

This was measured for randomly selected ten pods plucked from the earlier five plants in each plot and replications and recorded as pod length in centimeters.

3.6.2.3 Number of Seeds per Pod

This was determined by counting the number of seeds from the same selected ten pods that were used for measuring pod length from plot. Then the mean number of seeds per pod was recorded.

3.6.2.4 Pod Yield (kg /ha)

Plants from the two middle rows were harvested, sun-dried and weighed to record pod yield per plot and then converted into pod yield (kg/ha) by using the formula :

$$\boldsymbol{Pod\ yield\ (kg/ha) = \frac{Pod\ yield\ (kg)}{Harvested\ area\ (m^2)}\ X\ 10,000 m^2}$$

3.6.2.5 Seed Yield

The pods from the harvested plants from the two middle rows were threshed, and the weight of the seeds was recorded at safe moisture content and also converted using the formula:

$$\boldsymbol{Seed\ yield\ (kg/ha) = \frac{Seed\ yield\ (kg)}{Harvested\ area\ (m^2)}\ X\ 10,000 m^2}$$

3.7 Data Analysis

All data were subjected to analysis of variance (ANOVA) using Genstat 12 Statistical Package. Least significant difference (LSD) test was used to determine the difference in means at 5% probability. Linear Regression analysis was done to determine the relationship between seed borne pathogens and germination using transformed data.

CHAPTER FOUR

4.0 RESULTS

The results of the study are presented in Tables 4.1 to 4.16 showing the physical properties, the proximate analysis and their effect on the growth, yield, seed health, germinability and vigour of both original and harvested seeds of cowpea used in the investigations.

4.1 The physical properties of the cowpea seeds of the varieties used for planting

Table 4.1 shows the physical properties of the cowpea varieties used in the investigations. The seed length of the cowpea varieties used ranged between 5.92 mm and 7.69 mm and these differences were significant. Asontem seeds were longer than Soronko, Tona and Nhyira varieties ($P<0.05$). There were also significant differences among the length of the seed sizes. The large seed sizes were significantly longer than the small sized seeds ($P<0.05$). In contrast, there were no differences found among the seed width of the cowpea varieties tested. The large seeds had bigger width than the small seeds and the differences were significant. There were no significant differences among the 1000-seed weight of the cowpea varieties, but there was a difference for the 1000-seed weight between the two seed sizes. The large seed size had significantly higher value of 1000-seed weight (140.8 g) than the small seed size (102 g). Varieties x seed size interactions among the physical characteristics were not significant.

Table 4. 1 : Physical properties of the cowpea varieties planted

	1000 seed wt. (g)			Seed length (mm)			Width (mm)		
Variety	**L**	**S**	**Mean**	**L**	**S**	**Mean**	**L**	**S**	**Mean**
Asontem	141	101.5	121.2	8.95	6.43	7.69	6.80	4.52	5.66
Nhyira	140.2	102.8	121.5	6.91	4.94	5.92	5.76	4.46	5.11
Soronko	140.5	101.8	121.1	7.93	5.68	6.81	5.79	4.49	5.14
Tona	141.2	102.0	121.6	7.93	5.68	6.81	5.79	4.49	5.14
Mean	140.8	102.0		7.93	5.68		6.04	4.49	
Lsd (5%)									
Variety	6.04ns			0.46**			0.747ns		
Seed size	4.27**			0.33**			0.53**		
Variety x size	8.54ns			0.65ns			1.06ns		
Cv (%)	4.8			6.5			13.6		

L= large size, S= small size, (ns)= not significant, (**)(*)= significant at (1% and 5%) probability respectively

4.2 Proximate composition (%) of original seeds of the cowpea varieties

The moisture content of the different cowpea seeds was not significantly different among the varieties. There was significant difference between the seed sizes in terms of moisture content (Table 4.2). The moisture content of the large seed size was significantly higher than the moisture content of small seed size. The crude protein content was not affected by cowpea varieties. There was variation between seed sizes in protein content. The large seeds had protein content significantly ($P<0.05$) different from small seed size. The crude fat content of the cowpea varieties were not significantly different. For seed sizes, the large size had the higher value of fat content (1.78%) than small seed size (1.68), and there was significant difference. The crude fibre content of Asontem, Nhyira, Soronko and Tona were the same (6.08%), there were no differences. Significant differences were observed in fiber content of the seed sizes. The large seed size had fiber content significantly higher than the small seed size. Variety x seed size interaction was significant for fiber content at ($P<0.05$) (Table 4.2). The large seed size of the four varieties had higher values of crude fiber content than the small sized seeds of the same varieties. The carbohydrate content of the cowpea varieties was not significant. The small seed size had higher value of carbohydrate significantly different ($P<0.05$) from large seed size. With respect to the ash content, there were no differences observed among varieties. There was difference between large and small seed size. The large seed size had significantly higher value of ash (4.44%) than the small seed size (4.18%). Variety x seed size Interactions for the proximate composition were not significant except for crude fibre content.

Table 4. 2 : Proximate composition (%) of cowpea seeds of the different varieties

Variety	Moisture			Protein			Fat		
	L	S	Mean	L	S	Mean	L	S	Mean
Asontem	9.26	9.16	9.21	22.98	20.96	21.97	1.77	1.67	1.72
Nhyira	9.27	9.16	9.21	22.65	20.85	21.75	1.78	1.68	1.73
Soronko	9.27	9.16	9.21	23.09	20.64	21.86	1.78	1.68	1.73
Tona	9.26	9.16	9.21	22.91	20.82	21.86	1.78	1.68	1.73
Mean	9.26	9.16		22.91	20.82		1.78	1.68	
Lsd (5%)									
Variety	0.02ns			0.27ns			0.02ns		
Seed size	0.01**			0.19**			0.02**		
Variety x size	0.03ns			0.38ns			0.04ns		
Cv (%)	0.2			1.2			1.4		

Variety	Fiber			Carbohydrate			Ash		
	L	S	Mean	L	S	Mean	L	S	Mean
Asontem	6.14	6.03	6.08	57.10	59.41	58.30	4.38	4.15	4.26
Nhyira	6.15	6.02	6.08	57.57	59.53	58.55	4.43	4.21	4.32
Soronko	6.13	6.03	6.08	57.13	59.80	58.47	4.53	4.18	4.35
Tona	6.14	6.03	6.08	57.28	59.58	58.43	4.44	4.18	4.31
Mean	6.14	6.03		57.29	59.58		4.44	4.18	
Lsd (5%)									
Variety	0.01ns			0.30ns			0.12ns		
Seed size	0.01**			0.21**			0.08**		
Variety x size	0.02*			0.42ns			0.16ns		
Cv (%)	0.2			0.5			2.6		

L=large size, S= small size, ns = not significant, (*, **)= significant at 1% and 5% probability respectively.

4.3 The effect of variety and seed size on germination and vigor

Germination Percentage: Seed germination was not affected by variety and seed size (Table 4.3). However, variety x seed size interaction was significant. Nhyira large and Asontem small seed sizes had significant higher germination ($P \leq 0.01$) than Soronko and Tona (Table 4.3). First count for varieties and seed sizes used as a vigor indicator, were not significant for seed size and varieties. Variety x seed size interaction was not also significant.

Seedling Dry Weight: there were no significant differences among varieties but there was significant difference between the seed sizes. The large seed size produced seedling dry weight (8.91 g) significantly higher than the small sized seeds (7.66 g) (Table 4.3). Variety x seed size interaction was not significant.

Electrical conductivity: variation was found between the seed sizes. The small seed size had higher value (28.72 µ S/ cm.g) significantly different from large seed. Among the varieties, there were no differences for conductivity value (Table 4.3). Variety x seed size interaction didn't affect seed electrical conductivity.

Table 4.3 : The effect of variety and seed size on germination and vigor of original seed

Variety	Germination %			First count (%)			Seedling dry wt. (g)			Ec (µ S/ cm.g)		
	L	S	Mean	L	S	Mean	L	S	Mean	L	S	Mean
Asontem	89.25	94.50	91.88	88.50	92.25	90.38	8.70	7.88	8.29	25.03	28.20	26.61
Nhyira	94.75	89.50	92.12	92.00	87.75	89.88	9.68	7.57	8.63	26.89	30.22	28.56
Soronko	91.75	91.75	91.75	89.00	92.25	90.62	9.81	7.47	8.64	24.48	27.50	25.99
Tona	92.50	93.00	92.75	90.25	89.75	90.00	7.45	7.70	7.57	25.87	28.97	27.42
Mean	92.06	92.19		89.94	90.50		8.91	7.66		25.57	28.72	
Lsd (5%)												
Variety	3.60ns			3.32ns			1.35ns			1.89ns		
Seed size	2.54ns			2.35ns			0.96*			1.34**		
Variety x size	5.09*			4.70ns			1.92ns			2.67ns		
Cv (%)	3.8			3.5			15.7			6.7		

(L) = large size, (S) = small size, (ns) = not significant, (*), (**) means significant at (1%) and (5%) probability respectively

4.4 Percentage of Seed borne fungi detected on cowpea seeds of the four varieties (original seeds)

On the four cowpea varieties tested for seed borne fungi, a total of nine (9) seed borne fungi were recorded. The mean percentage infection of seed borne fungi revealed by Blotter Method is given in (Table 4.4). *Aspergillus Spp* recorded the highest (30.3%) mean percentage infection while *Rhizopus spp* recorded the lowest (0.1%).

Table 4. 4 : Percentage infection of seed borne fungi on original seeds

Seed borne fungi	Asontem	Nhyira	Soronko	Tona	Mean fungi infection (%)
Aspergillus Spp	13.8	28.1	35.8	43.4	30.3
Botryodiplodia theobromae	0.0	0.0	0.5	0.0	0.1
Cercospora Spp	0.0	1.8	0.0	0.8	0.6
Cladosporium Spp.	32.5	32.3	7.5	5.0	19.3
Curvularia Spp	0.5	0.0	0.3	0.0	0.2
Fusarium Spp	21.1	6.7	27.5	17.0	18.1
Macrophomina phaseolina	2.3	4.5	58.5	10.5	18.9
Penicillium Spp	14.8	21.3	1.5	4.0	10.4
Rhizopus Spp.	0.0	0.3	0.0	0.0	0.1

4.5 The impact of seed borne fungi on germination percentage of original seeds and harvested seeds

The Linear Regression indicated that the relationships between the seed borne fungi and germination were not significant except for *Macrophomina phaseolina* and *Corynespora cassiicola* which had significant relationship with germination. For the original seeds, germination was significantly affected by *Macrophomina phaseolina* infestation. This resulted in 34 % reduction in the germination of the original cowpea seeds (Table 4.5). At harvest, *Macrophomina phaseolina* was still present on the seeds but caused less reduction (17 %) in germination. Instead, *Corynespora cassiicola* was found to be the fungi with significant adverse effects on germination, accounting for 38 % reduction in the germination of the harvested cowpea seeds (Table 4.5). Three of the seed borne fungi detected on the harvested seeds were not found on the original seeds which included: *Colletotrichum dematium*, *Corynespora cassiicola and Phoma exiqua* while *Rhizopus* spp. on the original seeds was not found on harvested seeds.

Table 4. 5 : Regression equation and coefficient of the relationship between seed borne fungi (x) and germination % (y) of original and harvested seeds.

Seed borne pathogen	Coefficients of regression for original seeds	P - value	r^2	Coefficients of regression for harvested seeds	P-value	r^2
Macrophom phaseolina	Y=-1. 073x + 95.96	0.0005	0.34**	Y=-15.060x + 101.70	0.0182	0.17*
Corynespora cassiicola				Y= -20.49x + 103.26	0.0002	0.38**

4.6 Seedling emergence, seedling establishment and plant height

Seedling emergence, seedling establishment and plant height of plants from the various cultivars and seed sizes are presented in Table 4.6. Varietal differences were observed in seedling emergence and establishment. There were highly significant difference (P≤ 0.001) in seedling emergence and seedling establishment (P≤ 0.05). Tona emerged in significantly (P≤0.001) 4 days before Asontem, Soronko and Nhyira. Tona also recorded the highest percentage (97.8%) of establishment while Nhyira recorded the lowest (87.2%). Seed size significantly affected emergence (P≤0.01) and seedling establishment at P≤ 0.05. Large seeds generally took longer (5days) to emerge than smaller seeds (4 days) whilst stand establishment of large seeds was significantly higher (P≤0.05) than smaller seeds (Table 4.6). Variety x seed size interactions were significant at *P* = 0.01only for emergence (Table 4.6). The small seed size of the four varieties emerged earlier (4 days) than that of large seed size (5 days) of the same varieties, except for Tona large seed size which also emerged earlier.

There were highly significant differences (P≤0.001) among the varieties in terms of plant height at 2 WAP (Table 4.6). Nhyira (11.84 cm) was significantly taller than Soronko (9.15 cm), from 2WAP to 6 WAP. There were no significant difference between Asontem and Nhyira but Asontem and Nhyira were significantly taller than Tona and Soronko from 3 WAP to 6 WAP. Plant height was affected by variety from 2 WAP to 6 WAP. Plants grown from large seeds were only significantly (P≤0.01) taller at 2 WAP and 3 WAP than plants grown from small seed size. (Table 4.6). Variety x seed size interactions for establishment and plant height were not significant.

Table 4.6 : The effect of variety and seed size on seedling emergence, seedling establishment and plant height of the varieties evaluated.

Variety	Days to field emergence			Establishment %			Plant height 2WAP			Plant height 3 WAP		
	S	L	Mean	S	L	Mean	S	L	Mean	S	L	Mean
Asontem	4.33	5.00	4.67	88.3	98.7	93.5	9.81	10.53	10.17	16.63	18.18	17.41
Tona	4.00	4.00	4.00	97.3	98.3	97.8	9.95	10.62	10.28	14.95	15.73	15.34
Soronko	4.00	5.67	4.83	84.7	93.3	89.0	8.80	9.50	9.15	14.24	14.83	14.53
Nhyira	4.00	5.00	4.50	84.0	90.3	87.2	11.33	12.35	11.84	17.75	19.47	18.61
Mean	4.08	4.92		88.6	95.2		9.97	10.75		15.89	17.05	
Lsd (5%)												
Variety	0.34**			7.11*			0.858*			0.843**		
Seed size	0.24**			5.02 *			0.607*			0.60**		
Variety x seed size	0.49**			10.05ns			1.21ns			1.192ns		
Cv (%)	6.2			6.2			6.7			4.1		

Variety	Plant height 4WAP			Plant height 5WAP			Plant height 6WAP		
	S	L	Mean	S	L	Mean	S	L	Mean
Asontem	32.00	31.53	31.77	42.6	40.4	41.5	45.2	43.5	44.3
Tona	24.77	25.00	24.88	34.3	35.3	34.8	36.8	37.7	37.2
Soronko	23.61	24.47	24.04	27.5	33.7	30.6	28.6	35.7	32.1
Nhyira	27.40	30.73	29.07	33.7	40.8	37.3	37.4	43.3	40.4
Mean	26.95	27.93		34.5	37.6		37.0	40.0	
Lsd (5%)									
Variety	2.69*			6.14*			7.07*		
Seed size	1.90ns			4.34ns			5.00ns		
Variety x seed size	3.80ns			8.68ns			9.99ns		
Cv (%)	7.9			13.8			14.8		

L= large size, S= small size, ns= not significant, (*)(**)=significant at 1% and 5% probability respectively.

4.7 Number of branches per plant

There were no significant differences among varieties in the number of branches produced, except at 3 WAP when Asontem produced significantly greater number of branches per plant than Soronko, Tona and Nhyira at P≤0.05. Seed size did not affect branch production and variety x seed size interactions were not significant (Table 4.7).

4.8 Fresh shoot weight

Results in Table 4.8 reveal that generally, variety and seed size did not significantly affect shoot fresh weight at all sampling periods. There was increase in shoot fresh weight from 2 WAP to 5 WAP, but dropped sharply from 5 WAP to 6 WAP. Variety x seed size interaction was not significant.

4.9 Dry Shoot weight (g)

Table 4.9 indicates the shoot dry weight of cowpea varieties. The seed size as well as the varieties did not produce significant differences in shoot dry weight at 5% probability level. From 2 WAP to 3 WAP the shoot dry weight for all the varieties was low, but increased sharply in 4 WAP. Seed size and variety had no effect on shoot dry weight. Variety x seed size interaction was not significant.

Table 4.7 : The effect of variety and seed size on plant branches

Variety	3WAP			4WAP			5WAP			6WAP		
	S	L	Mean	S	L	Mean	S	L	Mean	S	L	Mean
Asontem	2.60	2.73	2.67	3.87	3.80	3.83	3.93	3.87	3.90	3.93	4.07	4.00
Tona	1.53	1.33	1.43	3.67	3.27	3.47	3.93	3.53	3.73	4.00	3.60	3.80
Soronko	1.27	1.53	1.40	3.33	3.47	3.40	3.60	3.60	3.60	3.80	3.73	3.77
Nhyira	2.07	2.20	2.13	2.87	3.20	3.03	3.13	3.47	3.30	3.20	3.53	3.37
Mean	1.87	1.95		3.43	3.43		3.65	3.62		3.73	3.73	
Lsd (5%)												
Variety	0.90*			0.66ns			0.65ns			0.57ns		
Seed size	0.64ns			0.45ns			0.46ns			0.40ns		
Variety x seed size	1.23ns			0.93ns			0.92ns			0.81ns		
Cv (%)	38.2			15.4			14.4			12.4		

L=large size, S= small size, ns = not significant, (*, **) = significant at 1% and 5% probability respectively.

Table 4.8 : The effect of variety and seed size on fresh shoot weight (g) per plant of cowpea

Variety	2 WAP			3 WAP			4 WAP		
	S	L	Mean	S	L	Mean	S	L	Mean
Asontem	4.15	5.50	4.83	19.69	23.86	21.78	68.1	63.2	65.7
Tona	5.21	4.81	5.01	22.85	22.54	22.70	66.0	59.2	62.6
Soronko	3.94	4.84	4.39	18.02	21.75	19.88	37.9	63.3	50.6
Nhyira	5.46	5.81	5.63	21.47	24.25	22.86	57.3	67.6	62.5
Mean	4.69	5.24		20.51	23.10		57.3	63.3	
Lsd (5%)									
Variety	1.27ns			5.49ns			18.54ns		
Seed size	0.90ns			3.88ns			13.11ns		
Variety x seed size	1.80ns			7.76ns			26.22ns		
Cv (%)	20.7			20.3			24.8		

Variety	5 WAP			6 WAP		
	S	L	Mean	S	L	Mean
Asontem	85.2	95.2	90.2	84.3	66.7	75.5
Tona	101.6	83.3	92.5	75.4	85.5	80.4
Soronko	86.0	101.9	93.9	61.6	102.9	82.3
Nhyira	94.7	97.6	96.1	87.2	112.5	99.9
Mean	91.9	94.5		77.1	91.9	
Lsd (5%)						
Variety	37.85ns			39.06ns		
Seed size	26.76ns			27.62ns		
Variety x seed size	53.53ns			55.24ns		
Cv (%)	32.8			37.3		

L=large size, S= small size, ns = not significant, (*, **) = significant at 1% and 5% respectively.

Table 4. 9 : The effect of variety and seed size on shoot dry weight (g) per plant of cowpea

Variety	2WAP			3WAP			4WAP		
	S	L	Mean	S	L	Mean	S	L	Mean
Asontem	0.48	0.61	0.55	1.96	2.35	2.15	10.00	6.13	8.07
Tona	0.62	0.60	0.61	2.40	2.45	2.43	6.93	5.87	6.40
Soronko	0.47	0.57	0.52	1.94	2.34	2.14	4.00	6.27	5.13
Nhyira	0.62	0.67	0.64	2.20	2.45	2.33	5.87	7.07	6.47
Mean	0.55	0.61		2.13	2.40		6.70	6.33	
Lsd (5%)									
Variety	0.13ns			0.51ns			3.15ns		
Seed size	0.09ns			0.36ns			2.23ns		
Variety x seed size	0.18ns			0.72ns			4.46ns		
Cv (5%)	18.0			18.3			39.1		

Variety	5WAP			6 WAP		
	S	L	Mean	S	L	Mean
Asontem	10.00	12.67	11.33	16.5	11.4	13.9
Tona	13.07	11.20	12.13	15.1	17.8	16.4
Soronko	11.73	12.53	12.13	12.3	19.7	16.0
Nhyira	13.07	12.13	12.60	18.6	32.1	25.3
Mean	11.97	12.13		15.6	20.2	
Lsd (5%)						
Variety	3.86ns			13.75ns		
Seed size	2.73ns			9.72ns		
Variety x seed size	5.46ns			19.44ns		
Cv (%)	25.9			62.0		

L=large size, S= small size, ns = not significant, (*, **) = significant at 1% and 5% respectively.

4.10 Yield components of the crop

The results on the number of pods per plant, pod length (cm), pod weight per plant (g) and pod yield (kg/ha) are presented in Table 4.11. The result indicated that pod yield was not affected by variety and seed size. There were no significant differences (P>0.05) among the varieties and seed sizes in the number of pods per plant, pod length (cm), pod weight per plant (g) and pod yield (kg/ha) (Table 4.11). However, variety x seed size interaction in the number of pods per plant was significant. The small seed size particularly in the variety Tona and large seed size in Nhyira produced greater number of pods per plant than Soronko and Asontem (Table 4.11).

4.11: The effect of variety and seed size on seed yield

Results on the number of seeds per pod, seed weight per plant and seed yield per hectare (kg/ha) are presented in Table 4.12.

Seed size did not affect grain yield of cowpea varieties but modified yield components in distinct ways. Number of seeds per pod was significant among varieties. Asontem produced significantly (P≤0.05) greater number of seeds per pod than Tona, Soronko and Nhyira. Variety x seed size interaction was significant for seed weight per plant (g). Plant originating from small seed size in Tona produced higher seed weight per plant (Table 4.12).

Table 4.10 : The effect of variety and seed size on relative growth rate of cowpeas (grams/day)

	3WAP			4WAP			5WAP			6WAP		
Variety	**S**	**L**	**Mean**	**S**	**L**	**Mean**	**S**	**L**	**Mean**	**S**	**L**	**Mean**
Asontem	0.21	0.25	0.23	1.15	0.54	0.85	0.00	0.93	0.47	0.92	-0.19	0.37
Tona	0.26	0.27	0.26	0.65	0.49	0.57	0.88	0.76	0.82	0.29	0.94	0.61
Soronko	0.21	0.25	0.23	0.29	0.56	0.43	1.11	0.90	1.00	0.07	1.02	0.55
Nhyira	0.23	0.25	0.24	0.52	0.66	0.59	1.03	0.72	0.88	0.79	2.85	1.82
Mean	0.23	0.26		0.65	0.56		0.75	0.83		0.52	1.16	
Lsd (5%)												
Variety	0.07ns			0.44ns			0.60ns			2.03ns		
Seed size	0.05ns			0.31ns			0.42ns			1.43ns		
Variety x seed size	0.10ns			0.63ns			0.84ns			2.87ns		
Cv	24.7			58.8			61.0			195.5		

L=large size, S= small size, ns = not significant, (*, **) = significant at 1% and 5% probability respectively.

Table 4.11 : The effect of variety and seed size on pod yield

Variety	Number of pods/plant			Pod length (cm)			Pod weight/ plant(g)			Pod yield (kg/ha)		
	S	L	Mean	S	L	Mean	S	L	Mean	S	L	Mean
Asontem	15.00	11.67	13.33	16.47	17.07	16.77	24.77	22.43	23.60	2316	1922	2119
Tona	16.67	13.00	14.83	15.30	16.12	15.71	25.87	23.57	24.72	2172	1994	2083
Soronko	12.33	12.33	12.33	16.75	15.62	16.18	19.83	19.90	19.87	1870	1926	1898
Nhyira	12.00	16.00	14.00	15.99	16.86	16.42	19.17	25.53	22.35	1694	2359	2027
Mean	14.00	13.25		16.13	16.41		22.41	22.86		2013	2050	
Lsd (5%)												
Variety	2.68ns			1.24ns			4.49ns			512.0ns		
Seed size	1.90ns			0.88ns			3.18ns			362.1ns		
Variety x seed size	3.79*			1.75ns			6.36ns			724.1ns		
Cv (%)	15.9			6.2			16.0			20.4		

L=large size, S= small size, ns = not significant, (*, **) = significant at 1% and 5% probability respectively.

Table 4.12 : The effect of variety and seed size on the number of seeds per pod, seed weight per plant (g) and seed yield per hectare (Kg/ha).

	Number of seeds per pod			Seed weight per plant (g)			Seed yield (kg/ha)		
Variety	**S**	**L**	**Mean**	**S**	**L**	**Mean**	**S**	**L**	**Mean**
Asontem	13.00	13.00	13.00	17.83	16.20	17.02	1449	1292	1371
Tona	13.33	12.00	12.67	19.57	17.20	18.38	1461	1330	1396
Soronko	11.33	11.33	11.33	14.80	15.00	14.90	1252	1289	1270
Nhyira	11.67	11.33	11.50	13.20	18.47	15.83	1084	1491	1288
Mean	12.33	11.92		16.35	16.72		1312	1351	
Lsd (5%)									
Variety	0.88*			2.71ns			330.5ns		
Seed size	0.62ns			1.92ns			233.7ns		
Variety x seed size	1.25ns			3.83*			467.5ns		
Cv (%)	5.9			13.2			20.1		

L=large size, S= small size, ns = not significant, (*, **) = significant at 1% and 5% probability respectively.

4.12 Harvested Seeds

4.12.1 The physical properties of the cowpea varieties of harvested seeds

The length of the seeds of cowpea varieties ranged between 8.00 mm and 7.76 mm. The differences between the lengths of the cowpea varieties were not significant. The large seed size were significantly ($P<0.05$) longer (8.33mm) than small seed size (7.43 mm). There were no significant differences among the varieties in terms of seed width. But seed width was affected by seed size, the large seed size had broader width (6.34mm) significantly ($P<0.05$) different from small seed size (5.99mm). Variety x seed size interaction for seed width was significant at ($P<0.001$). Asontem large seed had broader width than the seed sizes of Tona, Nhyira, and Soronko. The 1000-seed weight of the cowpea varieties was not significant. However, 1000-seed weight was affected by seed size. The large seeds had higher value of 1000-seed weight (140.73 g) which was significantly ($P<0.05$) different from small seed size of 135.48 g (Table 4.13). Variety x seed size interaction was not significant.

Table 4.13 : The physical properties of the cowpea varieties of harvested seeds

Variety	1000 seed wt. (g)			Seed length (mm)			Width (mm)		
	L	S	Mean	L	S	Mean	L	S	Mean
Asontem	140.85	135.60	138.23	7.85	7.67	7.76	7.07	5.24	6.15
Nhyira	140.03	135.98	138.00	8.81	7.18	8.00	5.61	6.74	6.17
Soronko	141.30	134.98	138.14	8.32	7.43	7.88	6.34	5.99	6.16
Tona	140.73	135.35	138.04	8.32	7.43	7.88	6.34	5.99	6.16
Mean	140.73	135.48		8.33	7.43		6.33	5.99	
Lsd (5%)									
Variety	5.43ns			0.63ns			0.40ns		
Seed size	3.84*			0.44**			0.28*		
Variety x size	7.67ns			0.88ns			0.57**		
Cv (%)	3.8			7.6			6.3		

L=large size, S= small size, ns = not significant, (*, **)= significant at 1% and 5% probability respectively.

4. 12.2: Proximate composition of harvested seeds

Proximate composition of harvested seeds is presented in Table 4.14. The moisture content of the cowpea varieties was not significant. There was however, significant difference between the seed sizes in terms of moisture content. The moisture content of the large seed size (9.22%) was significantly (P<0.05) higher than small seed size (8.82%). There were no significant differences among the varieties for crude fat content. The differences in crude fat content for the seed sizes was significant (P<0.05). Large seed size had higher crude fat content (2.48%) different from small seed size (2.03%). The crude fibre content of the varieties was not significant. There were no significant (P>0.05) differences among the cowpea varieties in terms of carbohydrate content. With respect to seed size, there was a difference between the seed sizes. The small seed had higher carbohydrate content (56.33%) than large seeds (52.28%). There were also no significant differences among varieties in ash content. There was significant difference between the seed sizes in terms of ash with the large seed size having higher value of ash content than small seed size. Variety x seed size interaction for the proximate composition of harvested seeds was not significant (Table 4.14).

4. 12.2.1 Comparison of the proximate composition of the original and harvested seeds

There were no significant differences among the four cowpea varieties of both original and harvested seeds in all of the biochemical qualities namely: moisture content, crude protein, crude fat, crude fibre, carbohydrate and ash content (Tables 4.2 and 4.14). However, there were variations in terms of biochemical qualities between the seed sizes. The large sized seeds had the higher composition of the biochemical qualities than the small seed size in both harvested and original seeds except for carbohydrate content which was low in large seed.

Table 4.14 : Proximate composition (%) of harvested seeds

	Moisture			Protein			Fat		
Variety	**L**	**S**	**Mean**	**L**	**S**	**Mean**	**L**	**S**	**Mean**
Asontem	9.22	8.81	9.01	23.19	20.99	22.09	2.49	2.02	2.26
Nhyira	9.21	8.82	9.02	23.29	20.93	22.11	2.49	2.01	2.25
Soronko	9.22	8.84	9.03	23.19	20.88	22.04	2.47	2.06	2.27
Tona	9.22	8.82	9.02	23.22	20.94	22.08	2.48	2.03	2.26
Mean	9.22	8.82		23.22	20.93		2.48	2.03	
Lsd (5%)									
Variety	0.15ns			0.12ns			0.07ns		
Seed size	0.11**			0.09**			0.05**		
Variety x size	0.21ns			0.17ns			0.10ns		
Cv (%)	1.6			1.1			3.0		
Variety	**Fiber**			**Carbohydrate**			**Ash**		
	L	**S**	**Mean**	**L**	**S**	**Mean**	**L**	**S**	**Mean**
Asontem	6.10	6.31	6.65	52.41	56.30	54.35	5.70	5.58	5.64
Nhyira	7.01	6.32	6.66	52.29	56.38	54.33	5.72	5.55	5.63
Soronko	7.01	6.31	6.66	56.14	56.32	54.23	5.72	5.59	5.66
Tona	7.00	6.31	6.66	52.28	56.33	54.31	5.71	5.57	5.65
Mean	7.00	6.31		52.28	56.33		5.71	5.57	
Lsd (5%)									
Variety	0.08ns			0.26ns			0.06ns		
Seed size	0.05**			0.19**			0.05**		
Variety x size	0.11ns			0.37ns			0.09ns		
Cv (%)	1.1			0.5			1.1		

L=large size, S= small size, ns = not significant, (*, **)= significant at 1% and 5% probability respectively.

4. 12.3 The effect of variety and seed size on germination and vigor of harvested seeds

Germination Percentage: Germination percentage for both seed sizes and all varieties ranged between 73.4 - 90.0% and there were no significant differences between seed size and among varieties (Table 4.15). First count for varieties and seed sizes used as a vigor indicator ranged from 70.6 to 84.1% and there were also no significant differences between seed size and among varieties.

Seedling Dry Weight: Seed size and variety did not significantly differ in seedling dry weight (Table 4.15).

Electrical conductivity: There were no significant differences among varieties for electrical conductivity result (Table 4.15). There was difference between seed sizes. The small seed size had higher electrical conductivity value (41.8) significantly ($P<0.05$) different from large seed (35.4). Variety x seed size interaction for germination and vigor of harvested seeds were not significant.

Table 4. 15 : The effect of variety and seed size on germination and vigor of harvested seed.

Variety	Germination %			First count (%)			Seedling dry wt. (g)			Ec (µ S/ cm.g)		
	L	S	Mean	L	S	Mean	L	S	Mean	L	S	Mean
Asontem	72.8	86.0	79.4	71.8	79.5	75.6	10.27	11.36	10.82	33.6	39.9	36.7
Nhyira	89.0	81.0	85.0	73.8	79.8	76.8	13.18	10.96	12.07	35.1	47.6	41.3
Soronko	93.8	86.2	90.0	85.2	83.0	84.1	13.32	12.31	12.82	37.2	39.0	38.1
Tona	75.2	71.5	73.4	70.5	70.8	70.6	9.53	11.29	10.41	35.7	40.6	38.1
Mean	82.7	81.2		75.3	78.2		11.58	11.48		35.4	41.8	
Lsd (5%)												
Variety	15.28ns			12.30ns			3.69ns			5.92ns		
Seed size	10.80ns			8.70ns			2.61ns			4.19**		
Variety x size	21.61ns			17.40ns			5.22ns			8.37ns		
Cv (%)	17.9			15.4			30.8			14.8		

L=large size, S= small size, ns = not significant, (*, **) = significant at 1% and 5% probability respectively.

4.13 Percentage of Seed borne fungi detected on cowpea seeds of the four varieties (harvested seeds).

On the seed samples of the four cowpea varieties tested for seed borne fungi of harvested seeds, a total of ten (10) seed borne fungi were recorded. The mean percentage infection of seed borne fungi revealed by Blotter Method is given in (Table 4.16). *Cladosporium spp.* recorded the highest (68.3%) mean percentage infection followed by *Aspergillus spp* (45.4%) while the lowest mean infections were recorded by *Cercospora spp* and *Curvularia spp* (0.6%). Three of the seed borne fungi detected on the harvested seeds were not found on the original seeds which included: *Colletotrichum dematium, Corynespora cassiicola and Phoma exiqua.*

Table 4. 16 : Percentage infection (%) of seed borne fungi detected on the harvested cowpea seeds

Seed borne fungi	Asontem	Nhyira	Soronko	Tona	Percentage infection (%)
Aspergillus spp.	45.5	42.4	48.3	45.3	45.4
Cercospora spp	0.0	0.0	0.0	0.3	0.1
Cladosporium spp.	67.8	63.5	66.8	75.3	68.3
Colletotrichum dematium	0.0	1.0	0.0	0.3	0.3
Corynespora cassiicola	0.0	4.3	0.0	0.0	1.1
Curvularia spp	0.3	0.0	0.0	0.0	0.1
Fusarium spp	12.9	30.4	28.8	42.1	28.5
Macrophomina phaseolina	2.8	3.5	0.8	0.8	1.9
Penicillium spp	7.3	10.5	16.0	28.8	15.6
Phoma exiqua	0.5	0.0	0.0	0.0	0.1

CHAPTER FIVE

5.0 DISCUSSION

5.1 Varietal differences in cowpea oil and protein content

Variations in oil content between seed sizes were significant. Similarly, variation in seed size protein content was significant. Large seed size was found to have higher oil and small seed size was found to have low oil and vice versa. This result corroborates the work of Kale *et al*. (1998) who reported positive association between seed mass and oil content in groundnut. Ries and Emerson (1973) also found protein to be positively related to seed size.

5.2 Germination Percentage

Malcolm *et al*. (2003) noted that increase in seed weight and seed size of Peach rootstock increased the germination percent. With increased seed size higher germination and emergence were determined in pearl millet (Kawade *et. al*., 1987). This indicated that seed size might have influence on germination in some crops but not in other crops. The result from this study disagrees with their findings and agrees with Main and Nafziger (1992) who reported that seed size has no effect on germination of seeds in winter wheat. Nhyira variety had different reaction from large size to next seed size compared to the other varieties in the original seeds used (Table 4. 3). The difference between Nhyira variety and other varieties is probably because of its superior genetic potential in 1,000-seed weight which shows more seed food storage. This result has been confirmed by Willenborg *et al*, 2005.

5.3 Seedling Dry Weight

The seedling dry weight was affected by seed size. The large seed size produced the highest seedling dry weight than the small seeds. This might have been attributed to the high 1000-seed weight and protein in large seed that resulted in high seedling dry weight. This result is in agreement with Guberac *et al*. (1998) who reported that seedling dry weight in larger seed sizes was related to more seed food storages in their endosperms. Each increase in size caused an increase in seedling dry weight.

5.4 Electrical conductivity

In the study, the four cowpea genotypes had no variation in water absorption. This means that seeds of the four varieties were intact and that the amount of electrolytes which leached through the seed coats was low. Large seed had low electrical conductivity values than small sized seeds in both original and harvested seeds. This might have been attributed to the fact that the seed coat of small seed size was not intact and also had low vigour as indicated by ISTA, (2007) that a higher conductivity may indicate a low vigor seed lot. Another reason could be attributed to fungal infection which might have resulted to low vigour in smaller seeds. Similarly, Shetty, (1990) reported that seedborne fungi cause maximum seed damage, which include reduced germination and vigour (Shetty, 1990).

5.5 The impact of seed-borne fungi on germination

The analysis of seed borne fungi associated with the seed indicated that most of the organisms identified had no effect on the germination percentage of the seeds before planting and after harvest. *Macrophomina phaseolina* was a major cause of germination reduction (Table 4.5) while *Corynespora cassiicola* was found only on harvested seeds and was also accounted for germination reduction. *Macrophomina phaseolina* has been reported to be transmitted from seed to seedling of sunflower (Bhutta *et al.,* 1996) and soybean (Anwar *et al*., 1995). Nabakka (1997) reported germination reduction of up to 59.3% as a result of *Macrophomina phaseolina* infection in cowpea seeds. In Northern Brazil, *Corynespora cassiicola* is considered to be one of the worst pathogens of tomato (Kurozawa and Pavan, 2006). Based on the result, germination was reduced by *Macrophomina phaseolina* and *Corynespora cassiicola* even though some of the seed borne fungi indentified are pathogens while others are saprophytes. Saad *et al*. (1988) reported that many seed borne fungi on cowpea in India have been reported to reduce seed germination and produce symptoms on infected seedlings. According to (Halloin 1986), the vast majority of seed-borne fungi are harmless saprophytes; only a small number are seed transmitted or seed pathogens.

Nakawuka (1996) reported reduced germination in cowpea of up to 40% in untreated seeds and attributed the trend to seed-borne pathogens. *Botryodiplodia theobromae* causes seed to seedling transmission of the Black Kernel Rot in maize up to 90% (CABI, 2007). *Colletotrichum dematium* (Pers.) has also been found to cause anthracnose in cowpea in South Africa, and the pathogen is widely distributed especially where the

environmental condition during the growing season ranges from dry and hot to slight humid (Smith and Aveling, 1997).

The vast majority of seed-borne fungi are harmless saprophytes; only a small number are seed transmitted or seed pathogens (Halloin, 1986). The storage fungi, mainly comprising several species of *Aspergillus spp, Penicillium spp, Cladosporium spp., Curvularia spp., Rhizopus spp.* do not invade grains to any appreciable degree or extent before harvest (CABI, 1996), but they can cause severe discolouration of seed in storage resulting in germination failure, discoloured or otherwise damaged embryos or whole seeds, and production of mycotoxins that constitute a health hazard for man and animals (Dharam Vir, 1974).

The detection of these pathogens *Colletotrichum dematium, Corynespora cassiicola* and *Phoma exiqua* on the harvested seeds might have resulted from environmental condition during the growing season. According to (Tarr, 1972), there are many host and environmental factors which directly or indirectly affect the transmission rates of seedborne pathogens. Temperature, moisture, light and pH are the most important environmental factors which influence the infection of plants. These parameters, as they occur in air or soil or both media, also modify the transmission of seedborne diseases.

5.6 Emergence and establishment

Edwards and Hartwig (1971) reported that soybean emerged faster from small seeds than large seed size for hybrid. The slow emergence rates in large seeds was due to dry soil conditions as the amount of moisture needed for germination was inadequate. Singh *et al.* (1972) also reported that large seeds of soybean had greater supply of stored

reserve to support early seedling growth and subsequently affected plant growth and development. The small seed size in this study emerged earlier (4 DAP) than the large seeds which emerged in 5 DAP. This may be due to the fact that the smaller seeds had access to water for faster emergence than larger seeds because of its size as the seeds were sown in the dry season. This observation agrees with earlier work by Edwards and Hartwig (1971). Earlier emergence was also observed in small sized seeds of all the varieties (Table 4.6).

Seedlings from larger seeds established well and had faster growth than the small seeds. The relatively high establishment rate in favour of large seed size is in agreement with work done by Swank *et al.* (1993) who reported that seedlings from larger and heavier seeds utilized cotyledonary reserve (UCR) at a faster rate to have greater rate of stem elongation and accumulation of root and shoot dry weight than the other seed sizes. Again, FAO (1981) reported that, large seed size has greater nutrient reserve and usually produces strong seedlings with satisfactory development of root and stems.

Tona emerged earlier and also had higher establishment rate to the other genotypes. Nhyira registered the lowest percent seedling establishment. This may be due to varietal differences. This agrees with the work of Patel and Golayinka (1988) that, genotypes exhibited different growth and yield potential when there is better rainfall distribution.

5.7 Plant height

Gan *et al*. (2003) reported that the different chickpea cultivars may have different plant height, seed yield components and seed size distribution, but the size of seed planted had no significant impact on most of these parameters. Chastein *et al.* (1995) observed that

soft white winter wheat plant grown from large and medium seeds were taller, heavier and had more tillers than plants from small seeds. Cotyledonary reserve in large seeds has influence in the initial growth of crops but has little importance in subsequent growth once leaves emerge. In this study, plants grown from large seed were taller than those grown from small seed size in the initial stages of growth. Another reason could be that the large seeds had the capacity to mobilize storage reserves to growing seedling as was also reported by Ndunguru and Summerfield (1975b), that the high emergence of large cowpea seeds may be due to their capacity to mobilize storage reserves to growing seedling. The variation in plant height among varieties may be attributed to genetic makeup of the varieties. The results from this agrees with work done by (Gan *et al.*, 2003; Chastein *et al*., 1995; and Ndunguru and Summerfield 1975b).

5.8 Branches

Generally, seed size did not affect the number of branches. This agrees with Detroja *et al.* (1993) who found that the differences in seed size did not influence number of leaves, and branches. Variety had significant effect on branches production. This agrees with the work of Patel and Golayinka (1988) that, genotypes exhibited different growth and yield potential when there is better rainfall distribution.

5.9 Shoot fresh and dry weights

Large seeded plants had greater values of shoot fresh and dry matter. The shoot fresh and dry weight differences were not significant up to the final sampling as well plants from the various seed sizes and varieties. The result indicates that increase in shoot biomass with seed size agrees with the work of Knauft *et al.* (1990) who have reported increased plant vigour and yield of groundnut with large seed.

5.10 Yield

In the study, seed size did not affect pod yield. Pedersen (2006), working on soybean, reported that smaller and larger seeds of the same variety will have the same yield potential. Kenneth and Burton (2004), working with canola also reported that differences among seed size treatments were not observed for any of the measured agronomic characters. However, it has been reported that the effect of crop seed size on plant performance is the issue of critical importance in spring wheat (Stougaard and Xue, 2005). This means that differences in seed size might influence the yield components in some crops, but not in others. The finding of this investigation confirms the results of (Pedersen 2006; Kenneth and Burton (2004), and Stougaard and Xue, 2005). Previous work also verified that although large seeds of a common bean cultivar increased plant growth, they did not affect grain yield (Marcos Filho and Avancine, 1983; Perin *et al.*, 2002). In this work, variety and seed size did affect seed yield, but modified yield components. Small seed size of Tona variety yielded highest seed weight per plant as compared to the other varieties (Table 4.12). This might be the result of the genetic makeup of Tona.

5.11 Comparison of the proximate composition of the original and harvested seeds

According to Chinma *et al*. (2008), compositional differences in cowpea could be attributable to soil type, cultural practices, environmental condition and genetic factors. The lack of variation among varieties in proximate composition could be attributed to good storage environment before planting, and again after harvest these qualities were similar to that of protein (20.5 - 31.7%), carbohydrates (56.0 - 65.7%); fat (1.1 - 3.0%),

fiber (1.7 - 4.5%) and moisture (6.2 - 8.9%), (Onwuliri and Obu, 2002). However, these characteristics present a major advantage in the use of the cowpea varieties in nutritional products. The large seed size had higher values in all the proximate compositions than small seed size in both original and harvested seeds except with the carbohydrate which was high in small sized seeds than that of large seeds. Variation in carbohydrate content might be due to wrong measurement during the analysis. Ries and Emerson (1973) found protein content to be positively related to seed size.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

1. All the four varieties were observed to have similar vigor, physical, and nutritional attributes for both original and harvested seeds. Tona small seed size produced the higher number of pods per plant and seed weight per plant.

2. Plants from small seeds emerged earlier as compared to the large seed size. While plants from large seed size showed faster growth rate especially in the initial growth stage as expressed in the height but did not have advantage over small seeds up to the final growth period. The faster growth rate in plants from large seeds did not however, translate into remarkably higher yield as compared to that of the plants from small seeds.

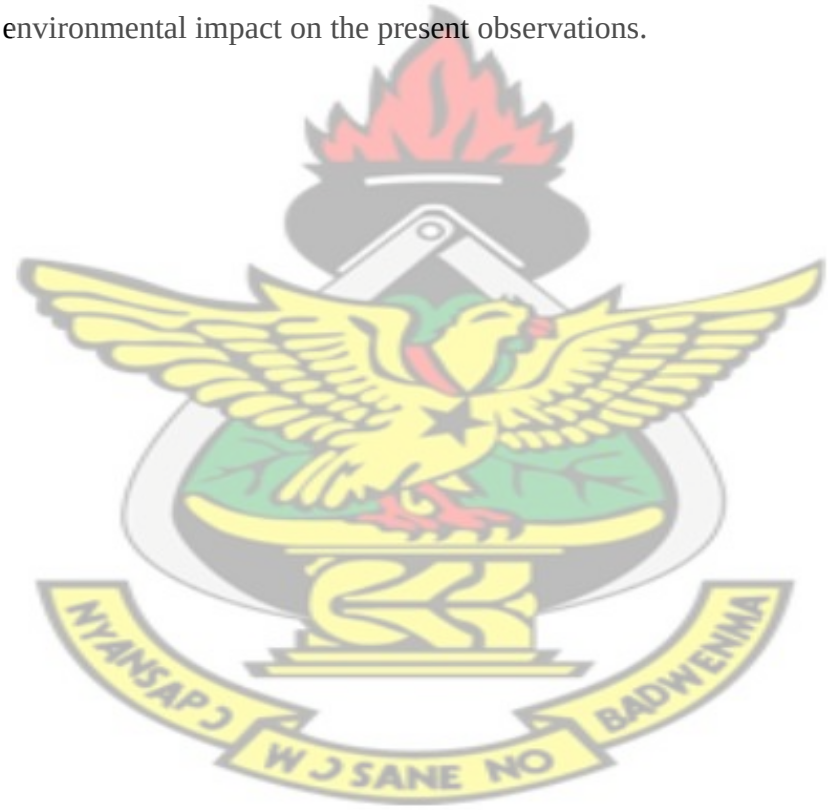
3. The result indicated that large seed do not have advantage over small seed in terms of germination, growth, as well as yield; sorting it out before planting will be of no economic return but time consuming.
4. The seed borne fungi caused reduction in germination.

6.2 Recommendations

1. Stakeholders in cowpea production should do proper seed selection as a means of reducing losses caused by seed-borne fungi, but not necessarily according to size but by use of certified seeds.

2. Future work should have field diseases assessed and compared to any diseases pathogens identified on the seed.

3. The study should be repeated in other ecological zones to study the environmental impact on the present observations.



7.0 REFERENCES

Abayomi Y.A., Ajibade T.V., Samuel O.F. and Sa'adudeen B.F. (2008). Growth and yield responses of cowpea (*Vigna unguiculata* (L.) Walp) genotypes to nitrogen fertilizer (N.P.K.) application in the Southern Guinea Savanna zone of Nigeria. *Asian Journal of Plant Sciences*. 7(2): 170-176.

Agarwal, V.K. and Sinclair, J.B. (1995). Principles of Seed Pathology. 2nd ed. Boca Raton, FL: CRC Press, Inc. 539 p.

Agarwal, V. K. and Sinclair, J. B. (1997). *Principles of Seed Pathology,* 2nd edition. CRC Press, Inc. Boca Raton, New York, London, Tokyo, pp. 538.

Agrawal R. L. (1995). *Seed Technology*. 2nd Edition. Oxford and IBH Publishing Co. Pvt LTD. India. 829 pp.

Aikins S.H.M. and Afuakwa J.J. (2008). Growth and dry matter yield responses of cowpea to different sowing depths. *ARPN Journal of Agricultural and Biological Science.* 3(5-6): 50-54.

Allen D.J. (1983): *The pathology of tropical food legumes*. John Wiley and Sons Chichester.

Anwar, S.A., S.F. Abbas, M.M. Gill, C.A. Rauf, S. Mahmood, S. and A.R. Bhutta. (1995). Seed-borne fungi of soybean and their effect on seed germination. *Pak. J. Phytopathol* , 7: 184-190

AOAC, (1990). Association of Official Analytical Chemists, 15th edition.Washington, D.C pp.1298.

AOAC, (1995). Official Method of Analysis, 16 ed; The Association of Official Analytical Chemists International, Arlington, VA.

AOSA (2002). Seed vigor testing handbook, No. 32. Association of Official Seed Analysts, Lab Crucas , N.M.

Aveling, T. (1999). Cowpea pathology research Analysis of postharvest systems; the GTZ concept GTZ, Germany. pp:7

Baalbaki R.Z, and Copeland L.O. (1997). Seed size, density and protein content effect on field performance of wheat. *Seed Sci. Technol*., 25:511–21.

Balkaya, A. and M. S. Odabas, (2002): Determination of seed characteristics in some significant snap bean varieties grown in Samsun, Turkey. *Pak. J. Biol. Sci.*, 5:382-387

Basu, R. N. (1990). Invigoration for extended Storability and Processing: International Conference on Seed Science and Technology. New Delhi.

Berg, T., Bjornstad, A., Fowler, C., and Skroppa. T., (1991). Technology Options and the Gene Struggle. NORAGRIC Occasional Peppers Series C., Development and Environment N^{0} 8., A. S. Norway

Bewly, J.D. and Black, M. (1994). *Seeds: Physiology of Development and Germination.* 2nd ed. Plenum Press, New York.

Bhutta, A.R., M.H. Rahber-Bhattti, M.S. Nazamni and I. Ahmad. (1996). Fungi associated with stored sunflower seeds in Pakistan. *Pak. J. Phytopathol* , 8: 139-143.

Bishaw, Z. and van Gastel, A. V. G. (1993). Seed Vigour and its measurement. In *Techniques in Seed Science and Technology*.South Asian Publishment Pvt Ltd.56 Sidharth Enclave, New Delhi, India.Pp.289.

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

Boerema, G. H. (1982). Ascochyta Phaseolorum Synonymous with Phoma exiqua. Neth. J. Plant Pathol 78(3):113-115

Bremner, P. M., R.N. Eckersall, and R.K. Scott. (1963). The relative importance of embryo and endosperrn size in causing the effects associated with seed size in wheat. *J. Agr. Sci*. 61: 139–145.

Bressani, R. (1985), Nutritive value of cowpeas. In Cowpeas: Production, Research and Utilization. Singh, S.R. and Rachie, K.O. (eds.) 353-359pp.

Burris, J. S., Wahab, A. H. and Edje, O. T. (1971). Effect of seed size on seedling performance in soyabean. *Crop Science* 11:492-496.

CABI. (2007). *Crop Protection Compendium*. 2007 Edition. Wallingford, UK: Centre for Agriculture and Biosciences International (CABI).

CABI (1996). *Seed Pathology and Microbiology*. Volue 7. Danish Government Institute of Seed Pathology for Developing Countries (CABI).

Cantliffe, J. D. (1998). Seed Germination for Transplants. *Hort. Technology* 8 (4). Florida Agricultural Experiment Station Journal Series N-01421.

Chaffai Amin and Louhichi Brinis (2013). Effect of seed size on germination and establishment of vigorous seedlings in durum wheat (*Triticum durum Desf*.). Advances in Environmental Biology, 7(1): 77-81, ISSN 1995-0756

Chastein, T. F., Ward, K. J. and Wysocki, K.D. (1995). Stand establishment response of soft white wheat to seed bed residue and seed size. *Crop science Journal* 35 (1): 44-65.

Chinma, C.E. Alemede I..C. and Emelife I..G. (2008). Physicochemical and Functional Properties of Some Nigerian Cowpea Varieties. *Pak. J. Nutr*., 7(1): 186-190.

Chopra, K. R., and Reusche, G. A., (1992). Seed Enterprise Development and Management.- FAO/DANIDA Trust Fund Publication. Bangkok.

Davis D.W., Oelke E.A., Oplinger E.S., Doll J.D., Hanson C.V. and Putnam D.H. (1991): Alternative plant and animal products: Programs in information exchange and research. In: *Alternative Field Crops Manual*. *New crops*. Janick and J.E. Simon (eds).. John Wiley and Sons, *New York*, pp. 133-143.

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

Demooy, B.E. and C.J. Demooy (1990). Evaluation of cooking time and quality of seven diverse cowpea (*Vigna unguiculata* (L) Walp.) varieties. *International Journal of Food Science and Technol*., 25: 202-212

Detroja, C. R., Sadaria, S. G. Kampara. V.D. Kaneria, B.B. and Malavia. D. D. (1993). Influence of time of shelling and seed size on yield. Quality and nutrient uptake in groundnut (*Arachis hypogaea* L.). Indian Journal of Agronomy 40:169-171.

Dharam Vir. (1974). Study of some problems associated with postharvest fungal spoilage of seeds and grains. *In:* Current Trends in Plant Pathology, S.P. Raychaudhury and J.P. Verma (eds.), Lucknow: Botany Department, Lucknow University. pp. 221-226.

Diekman, M. (1996). Seed-borne diseases in seed production. In. Seed Science and Technology. Proceedings of a train-the-trainers Workshop 24April to 9 May, 1993, Aman Jordan. (eds) A. J. G. van Gastel, Pagnotta, M. A. and E. Porceddu. International Center for Agricultural Research in the Dry Areas (ICARDA), Allepo Syria. Pp259-268

Dugje I. Y., Ekeleme F., Kamara A.Y., Omoigui L.O., Tegbaru A., Teli I.A. and Onyibe, J.E. (2009). Guide to safe and effective use of Pesticides for crop production. Canadian international Development Agency. www.iita.org. Retrieved March 2009.

Duke, J.A. (1981). *Handbook of Legumes of World Economic importance*. Plenum press, New York pp 345.

Edwards, C. J. and. Hartwig, E. E. (1971). Effect of seed size upon rate of germination in soyabean. *Agronomy Journal* 63:429-430.

Elias, L.G., Colindres, R. and Bressani, R. (1964). The nutritive value of eight varieties of cowpea (*Vigna sinensis*). *Journal of Food Science*, 29: 118-122.

Elias, S.; Garay, A.; Hanning, S. and Schweitzer, L . (2004). Testing the quality of seeds in cereals. Oregon State University Seed Laboratory, USA.

Erskine W. (1996): Seed size effects on lentil (*Lens culinaris*) yield potential and adaption to temperature and rainfall in West Asia. *J. Agric. Sci. (Camb.*) 126,335,341

Evans, L. E. and G. W. Bhatt. (1977). Influence of seed size, protein content, and cultivar on early seedling vigor in wheat. *Can. J. Plant Sci.* 57:929-35.

Fakir, G.A., Hossain, I., Ahmed, M.U., Asad-ud-Doullah, M. and Alam (2002). Quality of farmers Boro and T. Aman rice seeds collected before sowing from Bogra, Rajshahi and Rangpur districts of Bangladesh. A paper presented in the review and planning meeting of the Rice Seed Health Improvement (SHIP), PETRRA project held at BRRI, Gazipur, Bangladesh.

FAO. (1981). Cereal and grain-legume seed processing. Technical guidelines. 21:1-3.

FAO/UNESCO legend (1986). Technical Paper1. Soil classification and characteristization, FAO, Rome.

Farhoudi, R. and M. Motamedi, (2010). Effect of salt stress and seed size on germination and early seedling growth of safflower (*Carthamus tinctorius* L.). *Seed Sci. Technol*., 38: 73-78.

Fehr, W. R and Probst, A. H. (1971). Effect of seed source of soybean strain performance for two successive generations. *Crop Science* 11:865-867.

Fery R.L. (1990): The cowpea: production, utilization, and research in the United States. *Hort. Rev.* 12:197–222.

Finch-Savage W (1995). Influence of seed quality on crop establishment, growth and yield. In *Seed Quality: Basic Mechanisms and Agricultural Implications*: 361–384.

Fitter A.H. and Hay R.K.M. (1987). *Environmental physiology of plants*. *Academic Press, London* pp. 423-428.

Forbes, J.C. and Watson, R.D. (1992). *Plants in agriculture*. Cambridge University press; Cambridge, UK. pp.122.

Foster, S. A. (1986). Adaptive value of large seeds for tropical moist forest plants, a review and synthesis, *Botanical Review* 53: 260-299.

Frączek, J., Hebda, T., Ślipek, Z. and Kurpaska, S. (2005). Effect Of Seed Coat Thickness on Seed Hardness. *Canadian Biosystems Engineering*.Vol.47.Pp4.

Gan Y.T, Miller P.R and McDonald C.L (2003). Response of kabuli chickpea to seed size and planting depth. *Can. J. Plant Sci*. 83: 39-46. (SCI)

Gray, D. and J.R.A. Steckel. (1983). Some effects of umbel order and harvest date on carrot seed variability and seedling performance. J.GTZ concept GTZ, Germany. pp:7

Guberac, Martincic J. and Maric. S. (1998). Influence of seed size on germinability, germ length, rootlet length and grain yield in Spring Oat. Bodenkultur, 49:13-18

Hadidi A.N. (1996). Ecology Seed Germination Physiology. In. Seed Science and Technology, *Proceedings of a Train-the-Trainer Workshop*. Sponsored by Med-Campus Programme (EEC)24 April to 9May 1993, Amman, Jordan. ICARDA, Aleppo, Syria. Vii +311 Pp77.

Hall A.E. (2004): Breeding for adaptation to drought and heat in cowpea. *Eur. J. Agron.* 21: 447-454.

Halloin, J.M. (1986). Microorganisms and seed deterioration. In: McDonald, M.B.Jr. and Nelson, C.J. (eds.): Physiology of seed deterioration. CSSA Spec. Publ. No. 11: 89-99.

Hampton, G. J. and Coolbear, P. (1990). *Seed Science and Technology*. Proceedings of the International Seed Testing Association.Vol.18 (2). Pp 215-228.

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

Hampton, J.G., (1990). Herbage Seed lot vigour- do problems start with production? *Appl Seed prod.* 9: 87-93.

Harper, J. L. and M. Obeid. (1967). Influence of seed size and depth of sowing on the establishment and growth of varieties of fiber and oil seed flax. *Crop Sci*. 7: 527-532.

Harper, J. L., Lovell, P. H. and Moore, K. G. (1970). The shapes and sizes of seeds. *Ann. Rev. Ecol. Syst., 1*: 327-356.

Hendrix, S. D. (1984). Variation in seed weight and its effects on germination in *Pastinaca sativa* L. (Umbelliferae). *Am. J. Bot., 71*: 795-802.

Hopper W. W., Verholt, J.R.O. and Martin, J.R. (1979). Effect of cultivar temperature and seed size on the germination and emergence of soyabean. *Annals of Botany* (London) 44:301-308.

Houghton, P.J. (2006). Pharmaceuticals and pharmacologically active compounds. p. 490-498. In The Encyclopedia of Seeds: Science, Technology and Uses, M. Black, J.D. Bewley, and P. Halmer (eds.). CAB International, Wallingford, UK.

Howell, N., (1981). The effect of seed size and relative emergence time on fitness in a natural population of *Impatiens capensis* Meerb. (Balsaminaceae). *Am. Midl. Naturalist, 105*: 312-320. http://www.iita.org/cowpeahttp://www.iita.org/crop/cowpea.htm

Hunt, R (1978). *Plant Growth Analysis*. Edward Arnold, London, United Kingdom.

IBPGR (1983): International Board for Plant Genetic Resources: Descriptors for cowpea, IBPGR Secretariat, Rome, Italy.

IITA (2000): Crops and Farming Systems, last visited October 09, 2011. International Institute of Tropical Agriculture

IITA (2009). Cowpea http://www.iita.org/cowpea. International Institute of Tropical Agriculture

ISTA (1979).ISTA hand book for Seedling Evaluation. J. Bekendam, R. Grob (Eds) ISTA Germination Committee. Zürich, Switzerland. Pp 4- 7.

ISTA, (1985). International Rules for seed testing. *Seed Science and Technology*. 21 Suppl Seed prod,6:57-84.

ISTA (1986). ISTA *Handbook on Seed Sampling*. (Eds) A. Bould. International Seed Testing Association (ISTA) Zürich, Switzerland .Pp 1.

ISTA (1993). *International Rules for Seed Testing, Rules* 1993.International Seed Testing Association. Zürich, Switzerland.Pp 25.

ISTA (1996) International Rules for Seed Testing. *Seed Sci. & Technol.,* 29:1-355.

ISTA (2007). International Rules for Seed Testing, Rules. International Seed Testing Association, 2007 Edition, Chapter 5 Pp 1, Chapter 7 Pp 1.

ISTA, (2005). International Seed Testing Association. *International Rules for Seed Testing.*

Johnson, D.R. and Leuders, V.D. (1974). Effect of plant seed size on emergence and yield of soyabeans. Agron. J. 66:117-119.

Kale D.M, Gadgil J.D, and Murthy G.S.S. (1998). Relationship between seed size and protein contents in groundnut. Journal of Oilseeds Research **5,** 170-175.

Kawade, R. M., S. D. Ugale and R. B. Patil. (1987). Effect of seed size on germination, seedling vigor, and test weight of pearl millet. *Seed Res.*, **15:** 210213.

Kenneth E.L. and Burton L.J. (2004). Seed size and Seeding depth influence on canola emergence and performance in the Northern Great Plains. *A.J.* 96: 454-461.

Kiesselbach, T. A. and Helm, C.A. (1957). Relation of size of seed and sprout value to the yield of small grain crops. Neb. *Agro Exp. Sta. R. S. Bull*. 11.

Kloppenburg, J., (1988). *First the Seed; the political economy of plant biotechnology*. 1492-2000. Cambridge University Press. Pp. 349.

Knauft, D. A., Gorbet, D. W. and Wood, H.C. (1990). The influence of seed size on agronomic performance of a small seeded Spanish peanut line. Proceedings of Crop and Soil Science of Florida 135-9.

KNUST Agricultural Engineering Department (2012/2013). Meteorological section

Kuo, W.H.J. (1989). Delayed-permeability of soybean seeds: characteristics and screening methodology. *Seed Science and Technology*, Zurich, v.17,n.1,P.131-142.

Kurozawa, C. and Pavan, M. A. (2006). Doenças do tomateiro. - In: KIMATI, H. et al. (Eds.) Manual de fitopatologia. São Paulo: *Agronomia Ceres*. p. 607-626.

Langyintuo A.S., Lowenberg-DeBoer J., Faye M., Lambert D., Ibro G., Moussa B., Kergna A., Kushwaha S., Musa S. and Ntoukam G. (2003): Cowpea supply and demand in West Africa. *Field Crops Res* 82:215-231.

Larsen S.U. and Andreasen C. (2004). Light and heavy seeds differ in germination percentage and mean germination thermal time. *Crop Sci*., 44:1710-1720

Louwaars N.P., and De Boef W.S. (2012). Integrated seed sector development in Africa: A conceptual framework for creating coherence between practices, programs, and policies. *J. Crop Imp*. 26:39–59.

Louwaars, N. P. (1990). Commercial and Development Aspects of Seed Production. Paper presented at the first national Conference on Agricultural Research. Kampala.

Lowe, L. B. and S. K. Ries. (1972). Effects of environment on the relation between seed protein and seedlig vigor in wheat. *Can. J. Plant Sci*. 57:921-3.

Lowe, L. B., G. S. Ayers, and S. K. Ries. (1972). Relationship of seed protein and amino acid composition to seedling vigor and yield of wheat. *Agron. J.* 64:608-11.

Machado, J.C. (1988). *Seed Pathology: Basis and Applications*. MEC/ESAL/FAEPE, Brasilia, DF, Brazil

Main M.A.R, and Nafziger E.D. (1994). Seed size and water potential effects on germination and seedling growth of winter wheat. Crop. Sci. 34, 169-171.

Main M.A.R, and Nafziger E.D. (1992): Seed size effects on emergence, head number and grain yield of winter wheat. J. Prod. Agric. 5, 265-268.

Malcolm P.J., Holford P, Mc-Glasson W.B, and Newman S. (2003). Temperature and seed weight affect the germination of Peach rootstock seeds and the growth of root stock seedlings. *Sci Hor* 98:247-256. DOI

Marcos Filho J. and Avancine F. (1983) Tamanho da Semente de feijoeiro. *Pesq. Agrop. Bras*. 18:1001-1008.

Mathews, S. and A, A. Powell (1995). Seed Vigour and its measurement. In. *Techniques in Seed Science and Technology*. 2nd Edition. (Eds) Agrawal, P. K. and Dadlani, M. South Asian Publishers New Delhi, India. Pp 101.

Mathur, S. B. and Kongsdal, O. (2000). Common laboratory seed testing methods for detecting fungi. Danish Government Institute of Seed Pathology for Developing Countries, Denmark. 388 pp.

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

Maude, R.B. (1996). *Seed borne diseases and their control*. CAB International, Cambridge. 280 pp.

Mayer, A. M., and Poljakov-Mayber, A., (1989). *The germination of seeds*. 4th Edn. Pergamon, Oxford.

McDonald, M. B (1980)). Assessment of seed quality. *Hort.Science* **15**: 784-788

Mckensie, B. D. and Tomes, D. T. (1980). Effects of seed size and germination, seedling vigour and cytoplasm leakage in wild oats and birdfoot trefoil. *Canadian Journal of Botany* 58:471-476.

Mew, T.W.; Misra, J.K. and Merca, S.D. (1994). A Manual of Rice Seed Health Testing, International Rice Research Institute, IRRI, Pp: 3.

MoFA (2005): Agriculture in Ghana, Facts and Figure, PPME, Ministry of Food and Agriculture Accra. P.26.

MoFA (2010): Cropped area for major crops in Ghana: Statistics, Research and Info. Directorate (SRID). Ministry of Food and Agriculture.

Muleba N., Ouédraogo J.T. and Tignegre J.B. (1997): Cowpea yield losses attributed to Striga infestations. *J Agric. Sci.* 129:43–48.mungbean [*Vigna radiata* (L.) Wilczek] seeds. *Asian J Plant Sci*., 2:1008–9

Mycock, D. J. and Berjak, P. (1995). The implications of seed associated mycoflora during store. In: Kigel, J.; Galili, G., eds. Seed development and germination. Marcel Dekker, New York, NY, USA.

Nabakka, L. D. (1997). Seed-borne fungi of cowpea with emphasis on seed transmission and effect of *Macrophomina phaseolina*. M.Sc. Thesis Makerere University 85 pp.

Nakawuka, C. K. (1996). Significance of fungi in seeds of cowpea (*VIgna unguiculata* L. Walp) grown in Uganda. Report to the Danish Government Institute of Seed Pathology for Developing Countries (DGISP). 43pp.

Ndunguru, B. J. and Summerfield, R. J. (1975b). Comparative laboratory studies of cowpea (Vigna unguiculata) and soybean (Glycine max) under tropical temperature conditions. I. Germination and hypocotyls elongation. E. Af. Agric. For. J. 41:58-64

Neergaard P. (1979). *Seed Pathology*. Vol. 1 and 2, Revised Edition. The Macmillan Press Ltd, London. 1191 pp.

Niangado O. (2010). Varietal Development and Seed System in West Africa: Challenges and Opportunities. Second Africa Rice Congress, Bamako, Mali, 22–26 March: Innovation and Partnerships to Realize Africa's Rice Potential. Retrieved February 14, 2013. Available online at: http://www.africarice.org/workshop/ARC/0P1%20Niangado%20fin.pdf

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

Obilana A.T. (1987): Breeding cowpeas for Striga resistance. In *Parasitic Weeds in Agriculture, Musselman LJ ed*. (Boca Raton, FL: CRC Press), pp. 243-253.

Onwuliri VA and Obu JA. (2002). Lipids and other constituents of *Vigna unguiculata* and *Phaseolus vulgaris* grown in northern Nigeria. *Food Chemistry* **78**: 1-7.

Onyeike E. N., T. Olungwe, and A. A. Uwakwe. (1995). Effect of heat treatment and de-fatting on the proximate composition of some Nigerian local soup thickeners, *Food Chemistry*, 53, 173-175

Patel,M. S. and Golayinka, B. A. (1988). Effect of water stress on yield attributes and yields of groundnuts. *Indian Journal of Agricultural Science* 58:701.

Pedersen P. (2006). Soybean seed quality in 2006. http://www.ipm.iastate.edu

Perin A., Araujoú A.P. and Teixeira M.G. (2002). Efeito de tqmanho da Semente na acumulacáo de biomassae nutrients e na produtividade do feijoeiro. *Pesq. Agrop. Bras* 37:1711-1718

Perry, D. A. (1981) (Ed.). Handbook of Vigor testing methods- International Seed Testing Association, Zurich.

Perry, D.A., (1984). Report of Vigour Test Committee, 1974- 1977. *Seed Science and Technology*., 6:159-181

Pieta-Filho, C. and Ellis, R.H. (1991). The development of seed quality in spring barley in four environments on germination and longevity. *Seed Science Res*. 1: 163-177.

Porter, W. M., Rachie, K. O., Wien, H.C., William, R. J. and Luse, R. A. (1974). *Cowpea germplasm catalog.* IITA, lbadan, Nigeria.

Purseglove, J.W. (1984). *Tropical crops: Dicotyledons* (volumes 1&2 combined), First edition published by Longman Group Limited, England, pp 719.

QDPI, (1988). Course Manual, International Course on tropical Pasture and fooder seed production. Department of Primary Industries, Queensland Government, Brisbane, Australia. Pp 128

Quaye W., Yawson I., Yawson R.M. and Williams I.E. (2009). Acceptance of Biotechnology and social-cultural implications in Ghana. *Afr. J. Biotechnol*. 8: 1997-2003.

Rachie, K.O., (1985). Introduction in Cowpea Production, Research and Utilization, i-xxviiipp (ed. S. R. Singh and K. O. Rachie)

Ries, S. K., and E. H. Emerson. 1973. Protein content and seed size relationships with seedling vigor of wheat cultivars. *Agron. J.* 65:884-6

Roberts, E.H. and Ellis, R.H. (1989). Seed physiology and seed quality in soybean. In: *Advances in legume science*, 297-311pp (ed. S.J. Summerfield and A.H. Bunting). Royal Botanic Gardens, Kew.

Rukavina, H., I. Kolak, H. Sarcevic and Z. Satovic, (2002). Seed size, yield and harvest characteristics of three Croatain spring malting barleys. Bodenkultur, 53(1).

Rusoke, D.G, Rubaihago, P.R. 1994. The influence of some crop protection management practices on yield stability of cowpeas. *African Crop Science Journal* **2**: 143-148.

Saad, S., Raghunathan, A.N. and Shetty, H.S. (1988). Seed mycoflora of Cowpea (*Vigna unguiculata* (L) Walp) and their pathogenic importance. *Seed Sci Technol*. **16:** 541-548.

Saverimuttu, T. and Westoby, M., (1996). Seedling longevity under deep shade in relation to seed size. *J. Ecol., 84*: 681-689.

Schippers, R.R. (2002). *African Indigenous Vegetables, An Overview of the Cultivated Species* –Revised Version on CD Rom. Natural Resource International Limited, Aylesford, UK. ISBN 0-9539274-5-8.

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

Sefa-Dedeh, S. (2005). Final report for USAID Associate Cooperative Agreement No. 641-A-00-03-0003. Ghana Private-Public Partnership Food Industry Development Program cited by Nagai, T. (2008). Competitiveness of cowpea-based processed products: A case study in Ghana. MSc. Thesis, Michigan, Michigan State University.

Shetty, H.S. (1990). Different types of damages in seeds caused by seed borne fungi. In: *Seed Pathology*. Edited by Mathur S.B. and Johs Jørgensen. TechnicalCenter for Agricultural and Rural Cooperation. Danish Government Institute of Seed Pathology for Developing Countries.

Shetty, H.S. (2000). Seed health testing and its role in plant protection. Proceedings, 1999-National seminar on Seed Science and Teschnology, (Shetty, H.S. and H.S. Prakash,Eds.). 1st Edn. *Dept. of Applied Botany and Seed Pathology*, University of Mysore, India, pp: 76-78.

Silva, W. P. K., Deverall, B. J., Lyon, B. R. and Molecular. (1998). Physiological and pathological characterization of *Corynespora* leaf spot fungi from rubber plantations in Sri Lanka. Plant Pathol., v. 47, n.. 2, p. 267-277.

Silvertown, J. (1981). Seed size, life span, and germination date as coadapted features of plant life history. *Am. Naturalist, 118*: 860-864.

Simic, B., Popovic, R., Sudaric, A., Rozman, V., Kalinovic, I. and Cosic J.(2007). Influence of storage condition on seed oil content of maize, soybean and sunflower. CCS *Agriculturae Conspectus Scienticus*.Vol. 72. No.3 Pp 211-213.

Singh, J.N., Tripathi, S.K., and Negi, P.S. (1972) Note on the effect of seed size

on germination, growth and yield of soybean (Glycine max (L.) Merr.). Indian J. Agri. Sci. 42(1) : 83-86.

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

Singh, B,B., Chamblis, O.L. and Sharma, B. (1997). Recent advances in cowpea breeding. In: Advances in cowpea research. Singh, B.B., Mohan Raj, D.R., Dashiell, K.E. and Jackai, L.E.N. (eds.), Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS), IITA, Ibadan, pp 30–49.

Singh, R. and Rachie, K.O. (1985). Resistance to pests of cowpea in Nigeria. *Bulletin of Grain Technology*, 21: 267-297.

Smith, C. C. and Fretwell, S. D. (1974). The optimal balance between seed size and number of offspring. American Naturalist 108:499-504.

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

Spears, J. P., Jordan, D. C and J. E Barley (2002). Peanut seed production. A guide for producers of Virginia type peanut seed. N.C Coop. *Ext. Serv. Bull*. AG- 662 pp 1-7.

Stanton, M.L. (1985). Seed size and emergence time within a stand of wild radish *(Raphanus raphanistrum* L.): The establishment of a fitness hierarchy . O e c o l e g i a

Stougaard R.N. and Xue Q. (2005). Quality versus quantity: spring wheat seed size and seeding rate effects on *Avena fatua* interference, economic returns and economic thresholds. *Weed Res*. 45: 351-360. (SCI).

Swank, J.C., Egli, D.B. and Pfeiffer, T.W. (1993). Seed growth characteristics of legumes differing in duration of seed fill. *Crop Science* 27:85-89.

Taiwo, M.A. and Akinjogunla, O.J. (2006). *African Journal of Biotechnology*, 5(19):1749-1756

Tanaka, Y. (1984). Assuring Seed Quality for Seedling Production: Cone Collection and Seed Processing, Testing, Storage, and Stratification. In. Forest Nursery Manual: Production of Bareroot Seedlings. Martinus Nijhoff/Dr.Junk Publishers, the Hague.Pp27 – 33.

Tarr, S. A. J. (1972). *The Principles of plant pathology*. Macmillan, London, UK, 632pp.

Taylor, A.G. and C.W. Ten Broeck (1988). Seedling emergence forces of vegetable crops. *Hort Science* 23:367.

Timko, M.P. and Singh, B.B. (2008). Cowpea, a multifunctional legume. In: *Genomics of Tropical Crop Plants*. Moore, P.H. and Ming, R. (eds.), Springer, New York, pp 227-257.

Tomer, S. P. R. and Maguire, D. J. (1990). Seed Vigour Studies in Wheat. *Seed Science and Technology*. Proceedings of the International Seed Testing Association.Vol.18 (2) Pp 383-392.

Tompkins, D.R. (1965). Broccoli maturity and production as influenced by seed size. *J. Amer. Sot. Hort. Sci*. 88:400-405.

Tropical Legume II Project (2012). The Bulletin of Tropical Legumes.

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

Warham E. J., Butler L. D. and Sutton B. C. (1990). Seed testing of maize and wheat: A Laboratory Guide. CYMMYT, CAB International, UK. 84 pp.

Weis, M. I. (1982), The effects of propagule size on germination and seedling growth in *Mirabilis hirsuta*. *Can. J. Bot., 60*: 1868-1874.

Westoby, M., Leishman, M. and Lord, J. (1996), Comparative ecology of seed size and dispersal. *Phil. Trans. Royal Soc., 351*(1345): 1309-1318.

Willenborg C. J., Wildeman J.C, Miller A.K, Rossnaged B.G. and Shirtliffe S.J. (2005). Oat germination Characteristics Differ among Genotypes, seed sizes, and Osmotic potentials. Crop Sci., 45:2023-2029

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

Wood D.W., Longden P.C. and Scott R.K. (1977): Seed size variation; its extent, source and significance in field crops. *Seed Sci. Technol*. 5:337-352

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

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

Zhang, J. and Maun, M. A. (1990). Seed size variation and its effects on seedling growth in *Agropyron psammophilum*. *Bot. Gaz., 151*: 106-113.

Zimmerman, J. K. and Weis, M. I. (1983). Fruit size variation and its effects on germination and seedling growth in *Xanthium strumarium*. *Can. J. Bot., 61*: 2309-2315

8.0 APPENDICES

APPENDIX A : Characteristics of the soil at the study area

Soil depth	0-15 cm
% Organic carbon	1.10
% Organic matter	1.90
% Total Nitrogen	0.13
Exchangeable Cations (Cmol/kg)	
K	0.57
Na	0.19
Ca	6.40
Mg	3.00
Al	1.20
H	1.20
Available P (mg/kg)	154.0
pH	4.71
% Sand	82.35
% Silt	7.85
% Clay	9.80
Soil Texture class	LOAMY SAND

APPENDIX B : EXPERIMENTAL FIELD LAYOUT AND DESIGN