KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI, GHANA

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE, DEPARTMENT OF HORTICULTURE

EFFECTS OF HARVESTING STAGES AND PERIODS OF SEED STORAGE ON SEED QUALITY CHARACTERISTICS OF THREE SOYBEAN (*Glycine max* (L) Merrill) VARIETIES

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

BY

ISAAC OSEI TUTU

SEPTEMBER, 2014

DECLARATION

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

…… ……..

ISAAC OSEI TUTU Date

(STUDENT)

…… …….

DR. B. K. Banful Date

(SUPERVISOR)

…….. …….

DR. S. AMOAH Date

(CO-SUPERVISOR)

……. …….

DR. F. APPIAH Date

(HEAD OF DEPARTMENT)

DEDICATION

I dedicate this work to my lovely father, Kingsley Osei Tutu (of blessed memory) and my dear mother, Comfort Serwaa, who has sacrificed everything to give me the best education. I am most grateful for your unflinching support throughout my education. You are the centre of my world.

ACKNOWLEDGEMENT

To God be the glory for His grace, mercy, psychological strength, enablement, protection, and sustenance throughout this work and in my entire life. I wish to express my deepest appreciation to Prof. (Mrs.) N. S. Olympio at the Department of Horticulture for her tolerance, receptiveness, guidance and massive input throughout this work. My next deep gratitude goes to Dr. Ben K. Banful for the directions, suggestions, massive input and numerous contributions in making this project a success. I am highly indebted to Dr. Stephen Amoah at the CSIR- Crops Research Institute (CRI) for his invaluable guidance, encouragement and constructive suggestions from the onset to the end of this project. Many thanks also due to Mr. Ralph Bam, Mr. I. O.O Ansa, and Mr. S. Gyasi Boakye, all at the CSIR-CRI for their encouragement and support throughout my masters' education. I am most grateful to Dr. James Y. Asibuo at the CSIR-CRI for provision of irrigation facilities during the seed production period for good development of the crop. I also acknowledge and appreciate Mr. Micheal Adu (CSIR-CRI) for his technical advice and numerous contributions during seed production period. I am grateful to Madam Adelaide Agyeman (statistician) at the CSIR- CRI and Mrs. Zippora Appiah-Kubi for her assistance during the seed health test. My acknowledgements would not be complete without extending tremendous thanks and appreciation to all my family members especially Sarfo Richard and course mates, namely John Vinoagbe, Rowland Addo, Samuel Apuri, Natalline Sonnie Baysah, Angela Amoah and Alberta Asi Ebeheakey. Lastly, I appreciate my good friend Edward Ken Essuman for his considerable input.

ABSTRACT

Field and seed storage experiments were carried out between September 2012 and June 2013 to determine the most appropriate harvesting stage and period of storing soybean seeds, with minimal effects on seed quality characteristics. The field experiment was established using 3 x 3 factorial in Randomized Complete Block Design (RCBD) with three (3) replications. The seed storage experiment was set up using 3 x 3 x 3 factorial arrangement in Completely Randomized Design (CRD) with four replications. The field experiment was conducted at the Research fields of CSIR-Crops Research Institute at Fumesua, Kumasi Ghana (01^{0}36'W; 06^{0}43'N) with the treatment of harvesting soybean pods at physiological maturity, one and two weeks after physiological maturity. Physiological maturity was determined when 90% of the pods on the plant turned brown. Growth and yield characteristics were evaluated during seed production period. Germination percentage, seed vigour, 1000 seed weight, moisture content, fungal infection, protein and fat contents were assessed before storage, three and six months. The study revealed that soybean varieties harvested at physiological maturity recorded the highest seed yield, germination percentage, vigour and fat content while those harvested two weeks after physiological maturity had the lowest in the parameters listed. It was observed that temperature and relative humidity readings were high and fluctuated under ambient storage conditions. The 1000 seed weight and moisture content increased under ambient storage conditions. Further, irrespective of the variety, harvesting stage and storage period, a total number of thirteen fungi species were identified on the three soybean varieties before and during storage. These pathogenic fungi species contributed in reducing the quality of the seed particularly germinability and vigour at six months of seed storage. The results obtained indicated that for good yield and seed quality, soybean pods should be harvested at physiological maturity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CRI	Crops Research Institute
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agricultural Organization
FFA	Free Fatty Acid
GMO	Genetically Modified Organism
ICARDA	International Centre for Agricultural Research in the Dry Areas
IITA	International Institute of Tropical Agriculture
ISTA	International Seed Testing Association
KNUST	Kwame Nkrumah University of Science and Technology
MT	Metric Tonne
SARI	Savanna Agricultural Research Institute
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIFEM	United Nations Development Fund for Women
USDA	United States Department of Agriculture

CHAPTER ONE

1.0 INTRODUCTION

Soybean (*Glycine max* (L) Merrill), belong to the family Leguminosae and subfamily, Papilionoideae. It is an annual leguminous plant native to the Eastern Asia (Dadson and Noureldin, 2001). According to Singh (2010), soybean originated from China, where it is considered the oldest agricultural crop. The leading producers of the crop are the United States of America (35%), Brazil (27%), Argentina (19%), China (6%), India (4%), Paraguay (3%), and Canada (2%) (USDA, 2010). These countries are also large exporters (Singh, 2010).

In Africa, the leading producers are Nigeria (592,000 MT), South Africa (332 MT), Uganda (176,333 MT), Zimbabwe (96,008) and Malawi (50,000 MT) (FAO, 2010). In Ghana, production level is very low and has been attributed to small acreages under production coupled with unimproved agronomic practices such as non application of fertilizers, fungicides, insecticides or herbicides (Asafo-Adjei *et al.*, 2005). At maturity, soybean contains 38% protein, 30% carbohydrate, 18% oil, 14% moisture and varying levels of vitamins and minerals, including calcium, folic acid, and iron (Sauvant *et al*., 2004). Nutritionally, it is an excellent source of protein, hence the seed is considered the richest plant food consumed in terms of food value (Kure *et al.*, 1998). Medically, soybean is helpful for brain development because it contains 3% lecithine amino acid (Akubor and Ukwuru, 2005). Agronomically, it enriches the soil by fixing atmospheric nitrogen in symbiosis with bacteria for its own use with benefits to subsequent crops (Asafo-Adjei *et al.*, 2005). Industrially, soybean is useful as lubricants, emulsifiers and plasticizers (Addai and Safo-Kantanka, 2006).

Despite the numerous benefits derived from the cultivation of soybean, its seed is structurally weak, inherently short-lived and easily subject to damage (Delouche *et al*., 1973; Hans *et al*., 1997). Soybean seed lots typically decline in quality faster than seeds of other agronomic crops (Fabrizius *et al.,* 1999; Usberti *et al.*, 2006). It has been reported that the short life span of soybean in storage could be due to certain factors including the high oil content and perhaps high moisture content (Balesevic-Tubic *et al*., 2007). Nkang and Umho (1996) also pointed out that one of the major constraints to the production of soybean is the rapid loss of seed viability and vigour during storage under ambient conditions. The loss of germination is much more acute under tropical conditions (Shelar *et al.*, 2008). Furthermore, Marcos-Filho *et al.* (1994) indicated that harvesting time was a critical step in soybean seed production because the seed deterioration actually began either in the field, during harvesting or after harvesting. In Ghana, several studies on soybean harvesting time had been done but unfortunately the emphasis has been on grain and not seed. Consequently, farmers are continually faced with the challenge of loss of seed viability and poor germination when the next production period gets underway. The objectives of the present study therefore were to;

(i) evaluate the plant growth, pod yield and seed yield performance of three varieties of soybean

(ii) determine the effect of stage of soybean harvest on seed physical, chemical and health qualities

(iii) determine the effect of stage of soybean harvest on subsequent seed germinability and vigour of the three varieties

(iv) determine the combined effect of soybean harvest stage and period of storage on subsequent seed quality, germinability and vigour.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Morphological and Botanical Characteristics of Soybean

Soybean is a herbaceous annual legume. It is usually erect, leafy and rather bushy. Cultivars range in height from 45 – 120 cm, with growth periods of 75 – 150 days (Onwueme and Sinha, 1991). The soybean consist of two cotyledons which represent approximately 90% of the weight, a seed coat of hull (8% of weight), and two much smaller and lighter structures, the hypocotyls and the plumule (Van-Eys *et al.*, 2004). The primary leaves are unifoliate, opposite and ovate (Dadson and Noureldin, 2001). The secondary leaves are trifoliolate and alternate, and compound leaves with four or more leaflets are occasionally present. The nodulated root system consists of a tap root from which emerges a lateral root system (Dadson and Noureldin, 2001). The tap root may penetrate the soil as far as 150 cm deep, but most roots are in the top 30-60 cm of the soil. Nodules, when present, are small, spherical and sometimes lobed (Onwueme and Sinha, 1991).

The small purple or white flowers are borne on short stalks arising at the nodes of the stems. They are predominantly self-pollinating but cross-pollination by insects does occur, and may be a problem in maintaining cultivar purity in the field. The pistil is simple and the ovary matures into a pod (Onwueme and Sinha, 1991). The pods are small, straight or slightly curved, and range in colour from light straw to nearly black. The pods contain one to four seeds, round to elliptical in shape. Popular commercial cultivars have straw-yellow seeds, but cultivars with greenish-yellow, green, brown or black seeds are also found (Onwueme and Sinha, 1991).

The fruit is the classical leguminous pod, and the seed is of various colours (light yellow, oil green, brown, red) and shapes (egg-shape or round), with a typical scar (van-Gastel *et al*., 1996). The stem, leaves and pods are covered with fine tawny or grey pubescence (Onwueme and Sinha, 1991). Most cultivars have a main stem that branches from the lower nodes. The extent of branching depends on environmental conditions (Onwueme and Sinha, 1991).

2.2 Varieties of Soybean

A large number of soybean varieties exist, producing soybeans that vary greatly in shape and colour. Soybean varieties which have been released by the Research Institutes and are grown in Ghana are Salintuya I, Salintuya II, Quarshie, Anidaso, Nangbaar and Jenguma (SARI, 2012). Asafo-Adjei *et al.* (2005) pointed out that Salintuya-1, Anidaso and Quarshie are medium maturing (101-110 days) varieties. Nangbaar is an early maturing (≤ 100 days) variety while Jenguma is late maturing (110-115 days).

Grain yield for Salintuya-1 and Anidaso is 1.2 -1.8 tons/ha (12 – 18 bags/ha). That of Quarshie is 1.5 – 2.2 tons/ha (15-22 bags/ha). Grain yield for Nangbaar is 1.5 – 2.5 tons/ha (15-25 bags/ha) and 1.7 – 2.8 tons/ha (17-28bags/ha) for Jenguma (Asafo-Adjei *et al*., 2005). Onwueme and Sinha (1991) pointed out that the world average yield is about 1,800 kg/ha and with proper management, it is not difficult to obtain 2,500 kg/ha.

Adu-Dapaah *et al.* (2005) reported that Nangbaar grows to a height of 42 cm and bears an average of 6 branches per plant. Two to three seeds are borne per pod. The immature pod is green while the mature pod is light brown in colour. It has a very good field emergence. On days to 50% flowering, they found the 50% flowering day for Nangbaar on day 45 at Fumesua (Adu-Dapaah *et al.*, 2005).

Adu-Dapaah *et al.* (2005) added that at percentage moisture content of 8.37±0.05, Nangbaar had one thousand seed weight of 115.5±7.2 g, percentage protein content of 43.00±0.18 and 16.77±0.23 for percentage fat. Adu-Dapaah *et al*. (2000), found the 50% flowering day for Anidaso on day 50 at Fumesua. Further, Adu-Dapaah *et al.* (2005) reported that at percentage moisture content of 10.03±0.03, Anidaso had one thousand seed weight of 96.08±8.2 g, percentage protein content of 46.38±0.08% and 16.45±0.07% for percentage fat. Seed length of Anidaso was found to be 6.59±0.35 mm and 5.66 ± 0.37 mm for seed width (Adu-Dapaah *et al.*, 2005). Denwar and Mohammed (2008) reported that Jenguma has an average plant height of 65 cm. It has average 50% flowering day on 45 day. It has a maturity period of 110-115 days with yield potential of 2.5 tons/ha.

2.3 Diseases and Pests Management of Soybean Seed

2.3.1 Diseases Management

Quality seeds have less disease and insect problem (Pratt *et al*., 2009). Fungi, bacteria, nematodes, and viruses are pathogens that cause the soybean diseases. These pathogens attack seed, seedlings, roots, foliage, pods, and stems (Pratt *et al*., 2009). Diseases result in various symptoms such as stand loss, leaf spots, wilting, and premature plant death. Some diseases are minor and cause only cosmetic injury, while others can cause yield loss and poor seed quality. The severity of disease is influenced by the presence and amount of the pathogen, variety selection, and environmental conditions (Pratt *et al*., 2009).

Mathur *et al.* (2003) stated that seed-borne fungi that are capable of producing symptoms on young seedlings or even cause death are species of *Alternaria, Ascochyta, Fusarium,*

Bipolaris, Colletotrichum, Macrophomina and Pyricularia. The vast majority of plant diseases are caused by fungal pathogens (van-Gastel *et al.,* 1996). The authors further reported that any part of the plant is subject to disease, which may occur at any stage: seed, seedling, growing plants (van-Gastel *et al.,* 1996). However, Agarwal (1995) reported that seed borne microflora association with seed does not necessarily result in disease condition. 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. Earlier, Neergaard (1979) had 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.

The consequences of planting infected seed depend on the pathogen in question (Wright *et al.,* 1995). For those diseases that are primarily soil or residue-borne, planting infected seed is less important. Effects of seed-borne pathogens 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 (Wright *et al.,* 1995). 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).

Agrios (2005) indicated that for a disease to occur, the three components (host, pathogen and environment) must come into contact and interact. If any of the three components is

zero, there can be no disease. Each of the three components can display considerable variability. As one component changes, it affects the degree of disease severity within the host (Agrios, 2005). The interaction of the three components of diseases generally referred to as the "disease triangle." Each side of the triangle represents one of the three components (Agrios, 2005). In every infectious disease, a series of more or less distinct events occurs in succession and leads to the development and perpetuation of the disease and the pathogen (Agrios, 2005). This chain of events is called a disease cycle. The primary events in a disease cycle are inoculation, penetration, establishment of infection, colonization (invasion), growth and reproduction of the pathogen, dissemination of the pathogen, and survival of the pathogen in the absence of the host (Agrios, 2005).

Disease management involves using cultural practices (crop rotation, residue management, etc), use of resistant varieties, and chemical control (fungicides) when needed (Pratt *et al*., 2009). Crop management that integrates several different disease management strategies generally improves success and the potential for profitable soybean production (Pratt *et al*., 2009). Monitoring soybean fields to detect the early stages of disease and pest outbreaks, and keeping good records on their occurrence and distribution allows for timely and economical application of management inputs. Correct identification of soybean diseases is essential for effective disease management (Pratt *et al*., 2009).

2.3.2 Insect Pests Management

Soybeans have few serious insect pests compared to other cultivated crops (Pratt *et al*., 2009). However, an abundance of non-pest and beneficial insects are typically present in soybean fields. Beneficial insects usually keep harmful insect populations below economic

thresholds. The potential for economic loss is possible each growing season, and growers should inspect fields regularly to check for insect damage. Good pest management is the result of sampling fields, evaluating plant damage, correctly identifying insects, and determining insect populations (Pratt *et al*., 2009). Thresholds vary with the development of the crop. Treatment for insects should occur only when plant damage or insect counts exceed economic thresholds. Before employing chemical control measures for insects in soybeans, growers should be relatively sure that yield increases and/or the elimination of further damage will offset insecticide and application costs. Evaluation of the extent of insect infestations and timing insecticide applications are best accomplished by regularly surveying fields. Economic thresholds establish for the major pests and applying insecticides should be based on careful scouting and using thresholds for the various pests. Economic thresholds may be based on insect counts or plant damage. Percent defoliation is often used for foliage feeders (Pratt *et al*., 2009).

Soybean is a relatively new crop in Ghana and therefore has few recorded insect pest problems. In many locations, insect pest damage to soybean may be negligible. In some areas however, leaf eating caterpillars and pod-sucking bugs may cause serious yield losses if not controlled. The pod-sucking bugs suck sap from the developing pods and seeds causing them to shrivel and drop-off (Asafo-Adjei *et al.*, 2005).

The legume pod borer, *Maruca vitrata* Fabricius is one of the major insect pests of grain legumes (e.g. pigeon pea, cowpea, mung bean and soybean) in the tropics and subtropics. The geographic range of ***M. vitrata*** extends from northern Australia and East Asia through sub-Saharan Africa (Sharma, 1998). The larval stages of ***M. vitrata*** are destructive within agricultural and forest eco-systems as they feed on the tender parts of the plant stems, peduncles, flower buds, flowers and pods (Singh and Jackai, 1988).

Its common names include the Maruca pod borer, Bean pod borer, soybean pod borer, Mung moth, and the legume pod borer. The soybean pod borer is considered one of the most destructive pests of beans, and is a major pest of cowpeas in most parts of Africa. In cowpea, a typical infestation by *M. vitrata* can cause yield reductions of 20 to 80% (Singh *et al.*, 1990; Sharma, 1998).

2.3.3 Rodents and Birds Control

Rodents (especially rats, mice and wild rabbits) can cause serious damage by eating the seedlings and the maturing green pods late in the season. Rodent damage is most common in weedy fields and weedy surroundings. Birds (such as doves and crows) also pick seeds after planting; eat cotyledons or seedlings and immature seeds in pods (Asafo-Adjei *et al.*, 2005).

Rodents and birds scaring can be done especially early in the morning and evenings. Weeds within the immediate vicinity of the farm should be cleared to destroy the hiding places of pests (Asafo-Adjei *et al.*, 2005).

2.4 Soybean Seed Maturity

Seed maturation is one of the main components of seed quality and a prerequisite for successful germination and emergence (Perry, 1982). Maturity in soybeans occurs when beans in pods turn yellow and are no longer green (Hurburgh *et al*., 2007). Asafo-Adjei *et al.* (2005) pointed out that soybean crop is mature when there is yellowing and shedding of leaves, yellowing and drying of pods (90-95%) and the seeds become hard and yellow

(90%). After maturity, no additional dry matter will be accumulated in the seed. All pods do not mature evenly and pods usually turn brown four to eight days after reaching physiological maturity (Hurburgh *et al*., 2007). According to Marcos-Filho *et al.* (1994), physiological maturity is a point where there is stabilization of dry matter translocation to the seeds. The seed reaches its maximum dry weight at physiological maturity (Khatun *et al.*, 2009). If the seeds are retained on mother plant after physiological maturity, physiological changes in seed may lead to formation of hard seeds or off colour seeds in pulse crops (Khatun *et al.*, 2009).

At the mature stage, seed moisture content would be about 15-18%. When about 95% of the pods are mature, the pods will change from yellow to grey, brown, tawny or pale yellow depending on the variety (Asafo-Adjei *et al.*, 2005). Sidibe *et al*. (1999) earlier indicated that seeds contain about 60% moisture at physiological maturity and about 15% moisture when the soybean plant is fully matured. Leaving soybean plants in the field past maturity and awaiting harvest exposes seed to adverse weather conditions that can reduce yield and quality (Boudreaux and Griffin 2008). Maturity dates of soybean vary within varieties ranging between 90-115days (Sidibe *et al*., 1999). Wilcox and Calvin (1992) reported that early maturing cultivars are more adversely affected by delayed harvest than late maturing. Soybean plants that mature early during hot, dry periods yield lower-quality seeds than those that mature after temperatures drop (Sidibe *et al*., 1999).

2.5 Harvesting of Soybean

Soybean maturity depends on the variety and requires timely harvesting to reduce excessive yield losses (SARI, 2012). At maturity, the pod is straw-coloured. Soybean

should be harvested at physiological maturity, that is when about 90% of the pods have turned brown for a non-shattering variety (e.g. Jenguma) but 80% for shattering varieties (e.g. *Salintuya* I and *Salintuya* II). Some newly released varieties such as Jenguma are low shattering but losses in yield may occur from other causes if harvesting is delayed. If left on the fields after pods are dry, the seeds begin to deteriorate, especially if it is still raining (SARI, 2012). For high quality seed, there should be prompt harvesting when leaves, pods and seeds change colour. If planting was timed based on the maturity class, harvesting would be done under dry conditions and seed quality will be high (Asafo-Adjei *et al.*, 2005).

Soybean can be harvested either manually (by hand) or mechanically (by machine e.g. combine harvesters). In Ghana, most farmers harvest soybean manually because their farms are usually small (0.25 to 2 ha). In manual harvesting, soybean plants are cut at soil level or uproot and heap at various points (Asafo-Adjei *et al.*, 2005).

Plants can be heaped on a cleared surface or tarpaulin (Asafo-Adjei *et al.*, 2005). If left on the field after the pods are dry, the seeds may shatter, especially in the north where the dry harmattan winds can speed up the shattering process (Asafo-Adjei *et al.*, 2005). Where available, a combine harvester can be used for harvesting. This practice is preferred for large scale farming. Combine harvesters thresh and partially clean harvested seeds right on the field. The use of combine harvesters also saves time and reduces the drudgery the farmer has to go through to harvest and thresh manually (Asafo-Adjei *et al.*, 2005).

Harvesting can be at mid-morning or late afternoon to prevent shattering. When harvest is by uprooting the plant, soil particles should be shake off to avoid seed contamination. Harvesting early in the morning should be avoided due to dew which may accumulate on

pods. It is important to harvest at physiological maturity to avoid diseases, pest attack and infestation and field weathering that result in seed deterioration (Asafo-Adjei *et al.*, 2005). Harvesting at physiological maturity also minimizes loss of crop to bush fire, theft and destruction by animals. It ensures good quality seed and better economic returns (Asafo-Adjei *et al.*, 2005). Philbrook and Oplinger (1989) indicated that postponing harvest after soybean reached maturity resulted in yield losses of 0.2% per day, which was attributed to plant deterioration, grain losses, decreased harvest efficiency, and reduction of net yield.

When beans are ready for harvest and are subjected to alternating periods of wet and dry weather, preharvest or shattering loss can be high (Kandel, 2010). Preharvest losses are influenced by the time of harvest and can be reduced by harvesting at physiological maturity. Preharvest losses are beans that have dropped on the ground prior to harvest (Kandel, 2010).

2.6 Effects of Harvesting Stages on Seed Quality

Generally the seed yield and quality parameters in any crop are associated with stage at which the seed crop is harvested (Vasudevan *et al.*, 2008). In early harvested seed crop, the seed quality will be very poor due to more number of immature and undeveloped seeds, while in delayed harvesting, seed quality are affected on account of field weathering (Vasudevan *et al.*, 2008). Hence harvesting of the seed crop at physiological maturity is better as seeds will be having maximum dry weight, higher viability and vigor, besides higher seed yield and yield attributing parameters (Vasudevan *et al.*, 2008).

Demir *et al.*, (2008) also indicated that the stage of maturity at harvest is one of the most important factors that can influence the quality of seeds. Harvesting too early may result in low yield and quality, because of the partial development of essential structures of seeds (Keller and Kollmann, 1999; Wang *et al.*, 2008). Whereas, harvesting too late may increase the risk of shattering and decrease the quality of seeds due to ageing. Adverse environmental conditions such as rainfall or precipitation may also result in sprouting of seeds on mother plants (Ellis and Pieta Filho, 1992; Wang *et al.*, 2008). Physiological maturity is a genotypic character which is influenced by environmental factors (Mahesha *et al.*, 2001). At this point of plant phenology, seeds attain maximum viability and vigor. Environmental conditions during seed development and maturity including temperature, water stress or excessive rain, nutrients shortage, diseases infection, and pest pressure influence seed quality (Delouche, 1980).

2.7 Time of Maximum Seed Quality

Seed crops should be harvested when quality traits of seed are maximal. However, the time of the occurrence of maximum seed quality during development and its association with seed and fruit features are greatly debated and show variation among crops and growing locations (Perry, 1982). According to Harrington (1972), seeds attain maximum quality at the end of the seed filling period, thereafter viability and vigor of seeds decline because they then begin to age. This stage was termed physiological maturity (Sanhewe and Ellis, 1996).

Harrington's (1972) hypothesis has been supported by other findings such as those with wheat (Rasyad *et al.*, 1990), maize (Tekrony and Hunter, 1995) and soybean (Tekrony *et*

al., 1984). Mahesha *et al.* (2001) also added that at physiological maturity, seed shall have maximum viability and vigour. However, several research reports have observed that maximum seed quality was only attained some time after the end of the seed filling period, thus contradicting Harrington's hypothesis (Ellis and Pieta-Filho, 1992, Venter *et al.*, 1996, Demir *et al.*, 2002).

The term "mass maturity" has been found to be a more appropriate term to describe the end of the seed filling period than "physiological maturity" which has been found to be potentially misleading (Ellis and Pieta-Filho, 1992). Thus, in different crops, the time of reaching maximum seed quality may be different and it can coincide with the end of seed filling period or after this time. However, maximum seed quality can be achieved when seeds are harvested at correct maturity stage (Copeland and Mcdonald, 1995). Seed quality begins to decrease after reaching maximum quality which can occur in delayed harvestings. If harvesting is delayed seed quality may decline due to diverse environmental condition such as high temperature, pests or damage by birds and animals (Copeland and Mcdonald, 1995). Maximum seed quality or physiological maturity may occur at the end of seed filling period or slightly after this phase (Eskandari, 2012).

2.8 Drying and Handling of Soybean Seed

Soybeans require special handling, drying, and storage in order to maintain market quality from field to processor (Pratt *et al.*, 2009). FAO (2010) pointed out that preparing for successful seed storage should begin with proper seed handling during harvesting and post harvest handling. The key steps for this include; Minimizing insect infestation in the field by timely harvest and removal of seed from the field; Eliminating insect-infested seed

before storage which in effect will remove sources of future infestation or contamination; Drying the seed sufficiently to prevent micro-organism growth, insect growth, and reduce the respiration rate of the seed; and treating the seed with a suitable traditional or chemical insecticide to control insect infestation. In a warehouse situation, fumigation with gas is done on a periodic basis (FAO, 2010). Because soybeans have a natural crack, beans must be conveyed and handled gently to minimize "splits" (Pratt *et al*., 2009).

Soybeans can be harvested without too much damage up to about 18% moisture. If soybean is harvested at moisture content much above 13%, artificial drying is necessary. Soybeans also split easily if they are dried too fast or are handled roughly (Kandel, 2010).

2.9 Storage of Soybean

The purpose of storage is to maintain harvest quality of product, not necessarily to improve it (Sisman and Delibas, 2004). Soybeans must be stored as a dry stable seed at or below the safe moisture condition for all seeds and grains (Pratt *et al.*, 2009). The amount of moisture in the seeds, coupled with the temperature within the store is probably the most important factors influencing seed viability during storage (Gokhale, 2009). Soybeans usually are traded on a 13% moisture basis, so harvesting, storing and selling soybean as close to 13% moisture (wet basis) as possible is to the farmer's advantage. Soybeans that have moisture content above 13% are likely to mold under warm conditions (Kandel, 2010). On the other hand, soybeans are more likely to split during handling when the moisture content is below 13% (Kandel, 2010). If the temperature of the stored beans is kept below about 15.56 °C (60 F) at 13% moisture, soybeans usually can be held for at least six months without mold problems. For storage under warmer temperatures or for

storage times longer than six month, the recommended moisture content is 11%. Soybeans that are harvested at 11 to 13% moisture can be placed directly into ordinary storage bins equipped with simple aeration systems (perforated ducts or pads and relatively small fans) (Kandel, 2010).

Reviewing methods of storage, University of Greenwich (1999) recognised three types, namely, traditional, improved traditional and modern types. With particular reference to West Africa, it was reported that cribs, baskets, metal tanks, mud silos, underground pits and jute/cotton bags are common methods of storage. Choice of the method to use for storing seed depends on the kind of seed (FAO, 1981). University of Greenwich (1999) pointed out that in modern times, storage may be indoor or outdoor, in bulk, in silos, in bags, underground or above ground. Storage facilities for seeds range from small freezers, miniature aluminium foiled tins, bottles, glasses or plastics, metal containers, jute and cotton bags, to huge cold rooms controlled by robots.

It was observed that an air-conditioned room maintained at 20 °C is conducive to store seeds for a season once the seed is packed in water-proof containers (Chin, 1988). Modified storage or controlled atmosphere storage have been harnessed to achieve long term storage. According to Lu Quanyu (1984), controlled atmosphere techniques have been adopted as main method of seed storage in China because of their efficiency in preserving seed quality. Chin (1988) reported that the latest form of modified storage in practice is cryogenic preservation mainly used for preserving genetic resources and is carried out at -196 °C. Again, Hong and Ellis (1996) also emphasized that sub-zero temperatures such as -10 to -20 °C are best for long term storage often required in genebanks for genetic preservation. Earlier, UNIFEM (1994) acknowledged the availability of a wide variety of storage techniques but concluded that the choice of the

technique to use depends on the quantity of seed to be stored, local construction materials and the climate.

2.10 Effect of Ambient Storage on Seed Quality

FAO (1981) reported that farmers in the developing world still store their produce including seed under the ambient environment. Basu (1995) indicated that serious losses of viability have been reported from areas believed to have suitable climate for the production and storage of seed. Chin (1988) added that storage under ambient conditions has been observed to affect seed quality in general and germination in particular. In tropical areas, such as Brazil, ambient temperatures of storage are observed above 20 °C, and the decrease in germination was more alarming (Dhingra *et al*., 1998). In general, storage for long or short term is improved under ambient humidity if the seed is well packaged (McCormack, 2004).

2.11 Seed Quality

Seed is a living biological product which acts as a catalyst to transform the genetic improvements of plant breeders into crop production potential (van-Gastel *et al.,* 1996). It is the most vital and crucial input for successful crop production. To play its role, the seed supplied to farmers should be of very high quality (van-Gastel *et al.,* 1996). Quality seed can be defined as seed of an improved variety which has varietal and physical purity, low moisture content, high germination and vigour, free from weeds and seed-borne pathogens, uniform, and properly processed for distribution to farmers (van-Gastel *et al.,*

1996). Earlier, Ellis (1992) indicated that seed quality is a broad term which encompasses several factors: seed health, varietal and physical purity, germination, vigour and sizes. According to van-Gastel *et al.* (1996), seed quality includes seed testing, seed certification and seed legislation. The authors reported *seed testing* as often the first step in enhancing the quality of the seed (van-Gastel *et al.*, 1996).

Several methods are available for testing the quality of seed before planting (ISTA, 2007). The ultimate object of making a test is to determine the value of seed for planting and the method used must be based on the scientific knowledge of seed and on the accumulated experience of seed analysts. The method must be accurate and reproducible. The main methods used in seed testing include: sampling, analytical purity, germination capacity, viability, vigour, seed health, moisture content, weight determination and varietal purity (ISTA, 2007).

Seed certification was defined as the process which documents that the seed in a sealed container fulfills the characteristics required by seed legislation as indicated on the attached label (van-Gastel *et al.*, 1996). Seed certification ensures that the seed sold to the farmers is of the indicated variety, sufficiently pure, of good germination capacity, and disease free (van-Gastel *et al.*, 1996). *Seed legislation* aims at promoting the overall development of agriculture, but does not guarantee that quality seed reaches the famer (van-Gastel *et al.*, 1996). The purpose of a seed law is to protect the farmer against unwitting purchase of poor quality seed. Seed laws must be enforceable and must fit the social, economic, and judicial make-up of the country (van-Gastel *et al.*, 1996).

2. 12 Components of Seed Quality

There are several different aspects of quality, which can affect a crop (van-Gastel *et al.*, 1996). The most important components of seed quality are physical purity, germinability, seed health, moisture content, varietal purity, vigour, size and uniformity. Aspects of quality also include seed treatment, packaging and labelling (van-Gastel *et al.*, 1996). Shu **(**2012) indicated that some attributes that define crop quality include: nutritional value (amino acid composition, protein content, micronutrients, vitamins, secondary metabolites, etc.), consumer preference (flavour, texture, colour, grain size/shape), pre- and post-harvest and industrial/technological characteristics (fibre traits, sucrose content, storage quality, sprouting, oil content, starches, processing, bread-making) (Shu, 2012). Each component is of great importance to the user under different circumstances, as poor quality in any one factor may result in reduced quality and partial or total crop failure (van-Gastel *et al.*, 1996).

2.12.1 Genetic Purity

Genetic or varietal purity refers to whether a variety is true-to-type, and it still has the original genetic make-up (van-Gastel *et al.*, 1996). Varietal or cultivar purity is an important attribute of seed quality, because it guarantees that the genetic make-up (agro-ecological performance) of the variety as defined by the breeding methodology is still present when the seed of improved varieties reaches the farming community (van-Gastel *et al.*, 1996). The genetic potential of an improved variety can only be exploited by farmers if the genetic make-up is not diluted during multiplication (van-Gastel *et al.*, 1996).

Adulteration of the genetic quality of a variety could come about through gross admixtures, excessive mutations or pollination by undesirable pollen (FAO, 2010). Elias *et al.* (2011) stated that genetic purity is best evaluated through a field trial in pre and post control test plots in which the percentage of off-types in a seed lot is determined. Seed companies typically conduct variety trials each season to evaluate the genetic quality of contract lots; ideally, the seed lot is evaluated in comparison to the parent stock seed lot and competitors' lots of the same variety (Elias *et al.*, 2011). Genetic purity evaluation can also include screening for transgene (GMO) contamination (FAO, 2010). Field inspection followed by roguing during the growing period of the seed crop is one of the steps taken to insure varietal purity in certified seed (FAO, 2010).

2.12.2 Physical Purity

Physical purity is a test to determine the percentage of the pure seed, other crop seed, weed seed, damaged seed and inert matter in the seed sample (FAO, 2010). This ensures that farmers buy seed of the required species and not inert matter (stones, chaff, etc.) and dangerous weeds or parasitic weeds (*Orobanche, Cascuta, and Striga*) mixed in the specific seed (van-Gastel *et al.*, 1996). van-Gastel *et al.* (1996) defined physical or analytical purity as the proportion of pure seed in a certain lot and the composition of the undesirable matter. Eskandari (2012) stated that the physical qualities of the seed in a seed lot are characterized by: minimum damaged seed, minimal weed seed or inert matter, diseased seed and near uniform seed size. It is possible to eliminate all these during processing (Eskandari, 2012).

2.12.3 Germination Capacity

According to ISTA (2007), germination of a seed in a laboratory test is the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favourable conditions in soil (ISTA, 2007). Percentage germination is determined by performing a germiantion test. Failure in germination may lead to total crop failure (van-Gastel *et al.*, 1996). Soybean seed with good germination, 80% as a minimum and free of weed seed, trash, and damaged beans are recommended to be used for planting (Pratt *et al*., 2009).

In storage, soybean seed rapidly loses its viability (Pratt *et al*., 2009). Shelar *et al.* (2008) pointed out that the germination potential (viability) is very short lived in soybean as compared to other oilseed crops and is often reduced prior to planting time. This loss of germination is much more acute under tropical conditions. These environmental conditions make very difficult to maintain its viability during storage (Shelar *et al.*, 2008). Khaliliaqdam *et al.* (2012) also stated that the germination potential of soybean seeds declines more rapidly during storage than it does in other grain crops.

According to Shelar and Shaikh (2002), irrespective of genotypes, the germination potential of soybean seeds decreased during storage. Similar results were obtained by Nugraha and Soejadi (1991) for soybean seed stored for six months under conventional conditions. They stated that in a group of tested varieties only one maintained germination above 80%. Different longevity of seed storage as well as storage conditions exerts significant influence on seed germination (Nkang and Umoh, 1997). Seed aging during storage is an inevitable phenomenon, but the degree and speed of decline in seed quality depend strongly, beside storage conditions, on plant species stored and initial seed quality

(Elias and Copeland, 1994; Balešević-Tubić *et al.*, 2005) as well as on seed genetic traits (Malenčić *et al.*, 2003).

2.12.4 Seed Vigour

Seed vigour contrary to germination, indicates the capacity of seed lots to produce good crop stand under sub-optimal field conditions (van-Gastel *et al.,* 1996). Vigour is affected by mechanical damage to embryo or seed coat, environment and nutrition of the mother plant, stage of maturity at harvest, seed size, senescence, attack by pathogens and drying temperature (van-Gastel *et al.*, 1996).

Several vigour tests have been developed to predict field establishment (van-Gastel *et al.*, 1996). These include physical test (seed volume, weight, size), biochemical test (tetrazolium, conductivity, respiration) and physiological test (standard germination, speed of germination, seedling evaluation, cold test, accelerated aging, controlled deterioration) (van-Gastel *et al.*, 1996).

Conductivity test – 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. The test gives an accurate estimation of membrane permeability (ISTA, 2007).

Seed lots having high electrolyte leakage, that is, having high leachate conductivity, are considered as having low vigour, whilst those with low leakage (low conductivity) are considered as having high vigour (ISTA, 2007).

In a study on soybean seeds comparing electrical conductivity among genotypes, Kuo (1989) observed the existence of variability in seed coat permeability. The author further stated that the electrical conductivity values of soybean seeds are also influenced by the degree of hardness of the genotype (Kuo, 1989).

2.12.5 Moisture Content

Quality seed should also have an acceptable moisture content to enable storage for longer periods (van-Gastel *et al.*, 1996). Since moisture content influences seed quality during harvesting, processing and storage, it should be kept low at all stages. High moisture content at harvest damages the seed coat, whereas during storage, it initiates fungal development, insect activity, heating and germination, which contribute to rapid seed deterioration. However, Low moisture content makes seed liable to mechanical damage during harvesting and processing (van-Gastel *et al.*, 1996).

Daun (1995) recommended that oilseeds storage for extended period is only possible if the seed moisture content is less than 10% or preferably dried to 8%. Soybean seeds stored at 11% moisture content or below are recommended for storing seeds under temperature between 5 and 8 °C and can be stored for two years without development of fungi, while seeds stored at 30 °C with the same moisture content can be infected by fungi within a few weeks and severely damaged after six months of storage (Acasio, 2010). Low levels of moisture content may also cause germination problems such as inducing secondary dormancy (van-Gastel *et al.*, 1996).

Moisture content tests can be carried out in the laboratory by the oven method, but portable moisture meters are available to make quick determination of moisture in seed production fields, while processing, or during storage to decide alternative measures (van-Gastel *et al.*, 1996). The object of the test is to determine the moisture content of seed by methods suitable for routine use (ISTA, 2007). The moisture content of a sample is the loss in weight when it is dried in accordance with rules. It is expressed as a percentage of the weight of the original sample (ISTA, 2007).

2.12.6 Seed Health

Seed health is a component of quality, as are viability, vigour and purity (van-Gastel *et al.*, 1996). Seed can serve as a vehicle for the dissemination of plant pathogens, which can result in disease outbreaks. Seed-transmitted pathogens include fungi, bacteria, nematodes and viruses. They can be transmitted as contaminants with seed, on the seed surface, or through seed infection (in the endosperm or embryo). The vast majority of plant diseases are caused by fungal pathogens. Healthy Seed is a prerequisite for a high-yielding crop (van-Gastel *et al.*, 1996).

However, in seed production scheme, all efforts are usually made to supply the farmers with pure seed of high germination capacity; little emphasis is put on the health aspects in its narrowest sense (van-Gastel *et al.*, 1996). The health of seed refers primarily to the presence or absence of disease-causing organisms, such as fungi, bacteria and viruses, and animal pests, including nematodes and insects, but physiological conditions such as trace elements deficiency may be involved (ISTA, 2007). Seed health testing can be carried out in seed laboratories in orders to assess seed sanitary quality (FAO, 2010).

Different methods for testing the health status of seeds exist (van-Gastel *et al.*, 1996). Some of the methods which are used widely in seed health laboratories include direct inspection, seed washing test, blotter method, seed extraction, embryo test method, agar plate method, growing-on test, indicator test, serelogical test and phage-plaque method (Neergard, 1979). General tests such as the blotter test and the agar plate test reveal a wide range of fungal and bacterial pathogens (van-Gastel *et al.,* 1996, Mathur and Kongsdal, 2001).

2.12.7 Seed Viability

FAO (2010) stated that seed can only fulfil its biological role if it is viable. Therefore, physically uniform seed of an adapted variety will be useless if it is low in germination or if it fails to germinate when planted. Seed viability is affected by a number of different conditions. Some plants do not produce seeds that have functional complete embryos or the seed may have no embryo at all, often called empty seeds (FAO, 2010).

Predators and pathogens can damage or kill the seed while it is still in the fruit or after it is dispersed (FAO, 2010). Environmental conditions like flooding or heat can kill the seed before or during germination. The age of the seed affects its health and germination ability: since the seed has a living embryo and over time, cells die and cannot be replaced. Some seeds can live for a long time before germination, while others can only survive for a short period after dispersal before they die (FAO, 2010). Seed viability can be tested in many easy ways (ISTA, 2007). A seed germination test is probably the most simple (ISTA, 2007). In storage, soybean seed rapidly loses its viability and a germination test is essential to determine quality (Pratt *et al*., 2009).

Other viability tests have been developed (ISTA, 2007). This include tetrazolium test, X-ray test and seed conductivity tests. The objects of these test is to make a quick estimate of the viability of seed samples in general (ISTA, 2007).

2.12.8 Seed Storability

Seeds need to have good storage quality to ensure that it maintains conditions until it is used for sowing. During seed storage, quality can remain at the initial level or it may decline to a degree that would cause the seed to be unacceptable for planting (Pratt *et al*., 2009). Some seeds are naturally short-lived (e.g. soybean, onion, peanuts etc.). Some seeds (e.g. tall fescue and annual rye grass), though look much alike, differ considerably (Gokhale, 2009).

Similarly, the genetic make-up of the lines (varieties) in the same kind also influences storability. Seeds are considered to be in storage from the moment seed reach physiological maturity until they germinate or are thrown away because they are dead (Gokhale, 2009). Gokhale (2009) further stated that factors affecting seed longevity in storage include the kind and variety of seed, initial seed quality, relative humidity and temperature during storage**,** moisture content, fluctuating environmental conditions, storage in extreme condition (like cold, hot, and over dried), seed health (seed affected by bacteria, virus and fungus as well as insects and mites), type of godown**,** rodents and birds infestation**,** seed treatment and fumigation, and period of storage in transit. The author again indicated that the amount of moisture in the seeds, coupled with the temperature within the store is probably the most important factors influencing seed viability during storage (Gokhale, 2009).

The thumb rule for moisture and temperature during storage is that 1% decrease in moisture content doubles the storage life of the seed and with every 5 °C reduction in storage temperature, the storage life of the seed is doubled (Harrington, 1972),. Then also, the sum of the percent relative humidity plus the temperature in degrees Fahrenheit should not exceed 100 for safe storage. Gokhale (2009) added that most storage problems arise from low quality seed placed in storage, seed being carried over for too long and seed stored in poor ventilated, hot or damp warehouse. Germination testing and seed moisture content is traditionally used to provide the data upon which storage decision is based (Hampton, 1990).

2.12.10 Seed Weight

Weight determination is useful for calculating the sowing or planting rate of all seeds marketed according to weight, since large sized and heavy seeds require a higher planting rate to produce the same plant population as small-sized and light seed. The object is to determine the weight per 1000 seeds of the sample submitted (ISTA, 2007).

2.12.11 Protein Content

Soybean is a high protein legume (Akubor and Ukwuru, 2005). Soybeans are also reported to be excellent sources of protein for either direct human consumption or indirect consumption through processed food or livestock production (Addai and Safo-Kantanka, 2006). Nutritionally, soybean protein is an excellent complement to lysine-limited cereal protein, hence the basis for the use of soy flour as an economical protein supplement in

biscuit, bread, pasta and other cereal products (Hegstad 2008). All seeds contain one or more groups of proteins that are present in high amounts that serve to provide a store of amino acids for use during germination and seedling growth. These storage proteins are of particular importance because they determine not only the total protein content of the seed but also its quality for various end uses (Shewry *et al.*, 1993).

Despite wide variation in their detailed structures, all seed storage proteins have a number of common properties (Shewry *et al.,* 1993). First, they are synthesized at high levels in specific tissues and at certain stages of development. Their synthesis is regulated by nutrition, and they act as a sink for surplus nitrogen. However, most protein also contains cysteine and methionine, and adequate sulfur is therefore also required for their synthesis (Shewry *et al.,* 1993). Differences in speed of water absorption verified in different species would be mainly related to seed chemical composition; higher protein content usually corresponds to a faster water uptake by soybean seeds (Shewry *et al.,* 1993). Despite the numerous health importance of soybean seed protein content, the negative correlation with yield remains a setback for cultivation of high protein soybean (Wehrmann *et al.,* 1987).

2.12.12 Fat Content

Soybean is a rich source of quality edible oil (Addai and Safo-Kantanka, 2006). Copeland and McDonald (2001) reported that the oil content in seed influences the equilibrium moisture content and seed storage life and that those high in carbohydrates are hydrophilic whilst those high in oil content are hydrophobic. However, when provided with certain

necessary storage conditions, oilseeds storage life may be extended (Copeland and McDonald, 2001).

The oil content of seeds can also affect seed storage life and consequently germination. According to O'brein (2004), hydrolytic rancidity can affect taste, odour and other characteristics of oil thereby affecting the storage quality. Bankole *et al.* (2005) submitted that melon seed is difficult to store because germination and vigour deteriorate quickly in storage due to the high oil content in the seed. Similar observations made by Simic *et al*. (2007) indicated that seed longevity is affected by seed oil content due to noticeable decrease and deterioration in stored seed oil content and thus affected seed quality particularly germination.

2.13 Factors Affecting Seed Quality

Soybean seed quality is affected during pre and post harvest periods (Shelar *et al.*, 2008). There are some factors affecting seed quality: moisture content, temperature, mechanical injury and disease infestation.

Seed moisture content: Moisture is one of most important factors affecting seed quality from the time seed mature in the field until they are planted (Eskandari, 2012). Moisture determines how long mature seed will maintain high quality. Seeds normally have high moisture content at the time of fertilization. During maturation seed water content tend to decrease (Eskandari, 2012). The initial phase of dehydration is slow, and is accelerated from the time the seeds reach maximum dry weight; at that time, seeds possess 35 to 55% moisture content for orthodox monocot and dicot seeds, respectively. This decrease in

moisture content proceeds until hygroscopic equilibrium is attained (Eskandari, 2012). From that point on, moisture content changes are associated with variations in relative humidity. However, seeds produced in fleshy fruits have a lower decrease in moisture content than seeds produced in dry fruits (Eskandari, 2012). Humid conditions leads to increases in seed moisture which reduce shelf life (Santos, 2007).

Temperature and Relative Humidity: Irrespective of initial seed quality, unfavourable storage conditions, particularly temperature and relative humidity, contribute to accelerating seed deterioration in storage (Fabrizius, *et al.*, 1999). Temperature determines how rapidly seed deteriorate in the presence of excess moisture either in field or in storage (Eskandari, 2012). High temperature coupled with excess moisture can reduce seed quality in a matter of hours. Seed quality loss occurs at a slower rate under cold conditions. Reducing temperature in storage helps to keep seeds for longer periods with high quality (Eskandari, 2012). It is necessary to reduce moisture content along with reducing temperature or else seed will die because of ice formation inside seed (Eskandari, 2012). Germination and seedling vigour are severely affected if seed is stored at high relative humidity and deterioration is much faster if the storage temperature is also high (Cantliffe, 1998).

Mechanical Injury: Mechanical damage is another major factor responsible for deterioration in seed quality during postharvest processing and storage (Shelar, 2007). Pratt *et al*. (2009) added that the amount and type of mechanical damage will influence both seed viability and potential seed performance. Soybean seed is poorly protected from mechanical injury (Pratt *et al*., 2009). The embryo is surrounded by a thin seed coat and the radicle-hypocotyl (parts which become the root and plant stem) lie against the base of the cotyledons. This positioning of the radicle-hypocotyl combined with the thin seed coat

make the seed very susceptible to mechanical injury (Pratt *et al*., 2009). Mechanical injury occurs during harvesting, drying, and conditioning of the seed. Damage appears as cracks or breaks in the seed coat, cracks in the cotyledons, and injury or breakage of the radicle-hypocotyl. Large seeds are generally more susceptible to mechanical damage than small seed. Seed exposed to weathering in the field or seed dried at high temperatures is more susceptible to mechanical damage (Pratt *et al*., 2009).

Disease: large number of pathogens is also associated with soybean seed which lead to the reduction in germination and storability of the seed (Shelar *et al.*, 2008). Wicklow (1995) reported that under commercial grain storage, fungi are the primary cause of seed deterioration which is depicted by loss of germinability, decrease in dry matter, increase fat acidity, grain heating, and ultimate sprouting.

2.14 Nutritive Changes in Storage

The chemical composition of seed with high oil content is related to specific processes occurring in seed during storage (Milosevic and Malesevic, 2004). Changes that occur in seed during aging are significant in terms of seed quality, the feature that, among other things, also implies seed longevity (Milosevic and Malesevic, 2004). Shrinking and breaking of seeds during storage are some of the physical changes that occurred in soybean seed in storage (Narayan *et al*., 1988a).

Physical, chemical and biochemical alterations may occur in soybeans, depending on conditions and storage duration (Narayan *et al.*, 1988b). The chemical composition of oilseeds causes specific processes to occur during storage. The seeds rich in lipids have limited longevity due to their specific chemical compostion. For example, soybean seed

storage demands special attention due to its oil content, otherwise processes may occur that lead to the loss of germination ability and seed viability (Balesevic-Tubic *et al*., 2007). Fungal activity can cause changes that are detrimental to nutritive value during storage of seed and grain products. Specifically, nutrients are lost because of changes in carbohydrates, protein, lipids, and vitamins (Bothast, 1978).

Carbohydrate: Conditions that favour fungal activity lead to carbohydrate decomposition. Sugars are consumed and converted into CO_2 and H_2O. At moisture levels of approximately 15%, seed loses both starch and sugar and the dry weight decreases (Bothast, 1978).

Protein: The total protein content of seed as calculated from its nitrogen content is generally assumed to be constant during storage (Bothast, 1978). However, as fungal deterioration advances and carbohydrate is used in the respiratory processes, protein increases when protein test is conducted and calculated. Bothast (1978) indicated that proteolytic enzymes produced by fungi can modify the proteins in seeds by hydrolyzing them into polypeptides and amino acids. Subsequently, fungi can convert these materials into fungal protein which can be nutritionally beneficial to animals. These effects are only significant at advanced stages of deterioration (Bothast, 1978).

Lipids: Because most molds have a high lipolytic activity, fats and oils in seed are readily broken down into free fatty acids and partial glycerides during the fungal deterioration of seeds. These changes are greatly accelerated when moisture and temperature are favourable for fungal growth (Bothast, 1978). Stored soybeans may undergo physical, physiological and chemical changes even under ideal storage conditions. Some of the changes may or may not have a negative effect on the final use of seeds and meal

depending on the degree of change. One common indicator of chemical change in stored soybean is the levels of free fatty acid (FFA) present (Padin *et al.*, 2002***).*** An increase of FFA above 1% may translate into lower quality of its oil content. Other important changes include decline in soybean seed viability, change in the grain colour, increase or decrease in its moisture, decomposition of phospholipids, and the denaturation of its protein (Sinclair, 1995***).***

2.15 The Effect of Production Environment on Seed Quality

Seed quality can be limited by environmental conditions both before and after physiological maturity, the stage of development at which the seed possesses its maximum dry mass (Indira and Dharmalingam, 1996). Dadson and Noureldin (2001) reported that during soybean cultivation, it is exposed to many environmental factors that may encourage or retard development and productivity. Some factors are natural (such as light, darkness, temperature, wind, and rain), while others are under the influence of man (such as the application of fertilizers and pesticides or by choosing planting date and methods, and other cultural practices) (Dadson and Noureldin, 2001). Soybean developmental stages are influenced by the interaction between growth stage and environmental factors. It is affected by different factors, such as genotypes, planting date, geographical location, and environmental conditions (Dadson and Noureldin, 2001).

Oil seeds are very sensitive to the harsh environmental conditions. It is hypothesized that their oil content readily oxidize, which deteriorate the seed health in storage (Kausar *et al*., 2009). Report by Pratt *et al*. (2009) indicates that weather conditions affect seed quality. Environmental conditions during seed development, the drying down period, or after

physiological maturity, while the seed remains in the pod in the field may greatly affect seed quality. Seed produced from later planting dates that reach maturity after hot, dry weather generally has higher germination and field emergence than seed that matures during hot, dry growing conditions. Lower initial germination and seed vigour have been attributed to high temperatures that occurred during the period from physiological maturity. Seed quality of earlier maturing varieties at a particular location is generally lower than that of later-maturing varieties (Pratt *et al*., 2009).

Seed quality deteriorates when soybeans remain in the field after physiological maturity has been reached (Pratt *et al*., 2009). Early-maturing varieties are affected more by delayed harvest than late-maturing varieties. High temperatures, high relative humidity, and precipitation will speed field deterioration of soybean seed. The decline in seed quality has been attributed to physical damage to the seed as a result of the wetting and drying cycle that occurs in most years. Seed vigour declines before decreases in standard germination are observed. Seed vigour is more sensitive to field deterioration than seed viability. Loss in seed vigour while the seed remains in the field is accelerated by warm, moist conditions (Pratt *et al*., 2009).

2.16 Seed Deterioration

Deterioration means the loss of some key physiological functions, which ultimately leads to loss of essential seed quality attributes like vigour and germination (FAO, 2010). The rate of deterioration varies between crop types. Starchy seeds, such as cereals generally have a slower rate of deterioration compared to oily and high protein seeds such as legumes, when all other factors such as temperature, humidity, and moisture content of the

seed are the same (FAO, 2010). For example, many legumes that are high in oil content, such as peanuts, and soybeans show a higher and more rapid rate of deterioration. Other legumes lower in oil content such as beans or cowpeas do not deteriorate as fast. Maize and millet deteriorate at a slower rate than legumes; rice has a very slow rate of deterioration in storage (FAO, 2010).

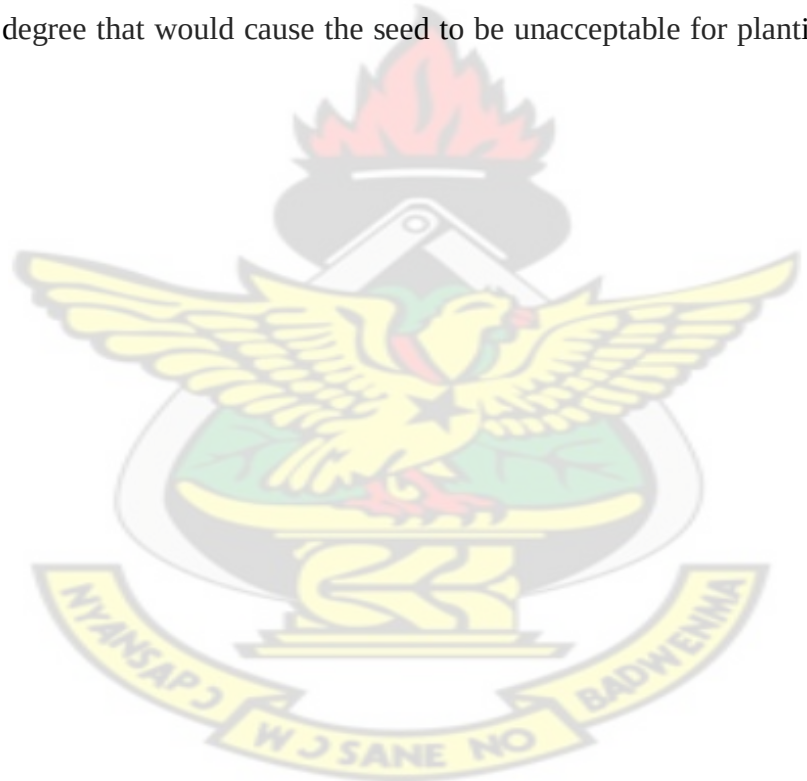
Differences also exist in deterioration rates among varieties of the same species (FAO, 2010). The moisture content of the seed is the most critical factor affecting the rate of deterioration. The optimum moisture percentage depends on the species and the temperature. The lower the seed moisture percentage is, the slower the rate of seed respiration (FAO, 2010).

A slower rate of seed respiration results in a slower rate of deterioration. Therefore, proper drying of the seed is critical for minimizing deterioration during storage (FAO, 2010). In tropical climates with high relative humidity during storage, seed moisture content can increase, which will increase the respiration rate and the deterioration rate of the seed (FAO, 2010). Higher seed moisture content is also favourable for insect infestation and growth of micro organisms (FAO, 2010). High moisture content combined with high temperature is an important factor in storage since higher temperatures increase the rate of seed respiration and seed deterioration. Sufficiently dry seed can withstand relatively high temperatures without significant deterioration. The lower the temperature and relative humidity the longer the seeds can be safely stored (FAO, 2010).

Seed deterioration is also associated with storage duration (Shelar, 2007). Changes associated with seed deterioration are depletion in food reserve, increased enzyme activity, increased fat acidity and membrane permeability. As the catabolic changes continue with

increasing age, the ability of the seed to germinate is reduced. Decline in viability or germination capacity does not begin immediately after maturation (Shelar, 2007). Under favourable storage conditions, the initiation of decline in germination may be from few months to many years depending on storage conditions, kind of seed and conditions during seed development (Shelar, 2007).

Seed deterioration leads to reduction in quality, performance and stand establishment (Shelar, 2007). As seed quality deteriorates during storage, vigour declines before loss in standard germination. During seed storage, quality can remain at the initial level but may decline to a degree that would cause the seed to be unacceptable for planting (Pratt *et al*., 2009).



CHAPTER THREE

3.0 MATERIALS AND METHODS

The study comprised of field and seed storage experiments. The field experiment was set up between September and December, 2012 whereas the seed storage experiment was from January to June, 2013. Laboratory analyses were conducted as part of each of the two experiments.

3.1 Experimental Field and Laboratory Locations

The field experiment was conducted at the CSIR-Crops Research Institute at Fumesua, Kumasi Ghana ($01^0$36'W; $06^0$43'N). Fumesua is in the semi-deciduous forest zone with elevation of 186m above sea level (ASL) and has a bimodal rainfall distribution. In the semi-deciduous forest zone, the major rainy season starts in late March and ends in mid-July. There is a short dry spell from mid-July to mid-September followed by the minor rainy season from mid-September to mid-November. The mean annual rainfall is 1500 mm. The mean minimum and maximum temperatures are 21 ^{0}C and 31 ^{0}C respectively. The mean annual relative humidity is about 60% at noon and 95% in the morning. The soil at the experimental site is ferric Acrisol (FAO/UNESCO legend, 1986).

The laboratory analyses were carried out at the Department of Biochemistry, KNUST (proximate composition - moisture, protein and oil), Department of Horticulture (seed storage, germination test and 1000 seed weight), Department of Crop and Soil Sciences (Seed conductivity test) and CSIR-Crops Research Institute (Seed health test).

3.2 Source of Seeds

Seeds of three varieties of soybean (Nangbaar, Anidaso and Jenguma) were procured from CSIR - Crops Research Institute (CRI) and CSIR - Savanna Agricultural Research Institute (SARI). The maturity classes of Nangbaar, Anidaso and Jenguma are early (≤100 days), medium (101-110 days) and late maturing (110-115 days), respectively (Asafo-Adjei *et al.*, 2005).

3.3 Field Experiment

The field experiment was set up in a 3 x 3 factorial arrangement in Randomized Complete Block Design (RCBD) with three replications. The first factor was variety at three levels (Nangbaar, Anidaso and Jenguma) whiles the second factor was stage of harvest also at three levels (harvesting at physiological maturity (H_0), one week after physiological maturity (H_1) and two weeks after physiological maturity (H_2). The land was manually prepared using the zero tillage technology. Seeds were planted in ten rows in each plot of 5 m long at spacing of 60 cm between rows and 10 cm within rows. Distance between replicates was 1 m. Three seeds were planted per hill and thinned to two, two weeks after planting.

No soil amendment or fertilizer was applied. Weeds were effectively controlled during the growing period. Monitored spraying was carried out at four and six weeks after planting with Lambda Super 2 SEC to control insect pests. Morphological data collected included 50% emergence, plant height, number of branches per plant and days to 50% flowering. Seeds were harvested at three different stages; harvesting at physiological maturity (H_0), and at one and two weeks after physiological maturity (H_1 and H_2 respectively).

Physiological maturity harvesting was carried out when 90% of the pods on the plant turned brown (SARI, 2012).

Pods harvested at physiological maturity were further dried for one week before threshing manually. No further drying was however done with pods harvested one and two weeks after physiological maturity. Following each harvest, yield characteristics (number of pods per plant, number of seeds per plant, seed yield per two rows and percentage shattering loss of seeds) and percentage purity were determined. Harvested seeds obtained were then stored and used for further laboratory analyses.

3.4 Data Collection

3.4.1 Fifty Percent Field Emergence

Four middle rows were selected from eight rows for data collection. Seedlings emerged were counted daily from the day of first seedling emergence until the day 50% of the seedlings emerged. The total number of days was then recorded as the number of days to 50% emergence for the treatment.

3.4.2 Plant Growth and Yield Measurements

Five plants were randomly selected from the four middle rows of each plot and tagged for the determination of plant height, number of branches per plant, number of pods per plant and number of seeds per plant.

3.4.2.1 Plant Height

Plant height (cm) was measured from the base to the growing tip of the plant using a metre rule. Measurement was done at two weekly intervals.

3.4.2.2 Number of Branches per Plant

The number of branches per plant was determined by counting at physiological maturity.

3.4.2.3 Days to 50% Flowering

Four middle rows were selected for the measurement of the number of days to 50% flowering. Counting started from the day the first plant flowered until the day 50% of the plants flowered. The total number of days was then recorded as the number of days to 50% flowering for the treatment.

3.4.2.4 Number of Pods per Plant

The number of pods per plant was counted at physiological maturity. The mean values were then computed.

3.4.2.5 Number of Seeds per Plant

The number of seeds per plant was counted at physiological maturity after which the mean values were computed.

3.4.2.6 Seed Yield

Two rows were used to evaluate seed yield of each varietal harvesting stage. A total of two hundred and four plants were used. After harvesting, threshing was done to remove the seeds from the pods. Seeds obtained were then weighed to determine the seed yield (g).

3.4.3 Percentage Seed Shattering Loss

Shattering loss of seed was determined by counting all loose beans and beans in loose pods on the ground (Kandel, 2010). The number of seeds that shattered was collected on a daily basis after observing first shattering on the field. The number of seeds that shattered was weighed with analytical balance and the percentage shattering loss determined from total seed yield.

3.4.4 Percentage Seed Purity

A representative sample of 500 g weight from each plot was separated into three components (pure seed, other crop seed and inert matter) through visual assessment (ISTA, 2007). The various components were then weighed and the proportional percentage of each component determined (ISTA, 2007).

3.5 Seed Storage Experiment

The seed storage trial was set up in a 3 x 3 x 3 factorial arrangement in Completely Randomized Design (CRD) with four replications. The first factor was variety at three levels (Nangbaar, Anidaso and Jenguma); the second factor was stage of harvest also at three levels (harvesting at physiological maturity (H_0), one week after physiological

maturity (H_1) and two weeks after physiological maturity (H_2) and the third factor was storage duration at three (no storage, three months storage and six months storage). Seeds were not treated with any chemicals or botanicals before and during storage. Seeds were stored in brown paper envelopes.

3.5.1 Data Collection

3.5.1.1 1000 Seed Weight

One thousand seed weight was determined by counting out at random 8 replicates of 100 seeds from the pure seed fraction. Each replicate was weighed with an analytical balance and the weight recorded. Then the average weight of the 8 replicates calculated, and multiplied by 10 (ISTA, 2007).

3.5.1.2 Temperature and Relative Humidity of Storage Room

The ambient storage room temperature and relative humidity readings were taken at specified times of 9:00 am, 12:00 pm and 6.00 pm. Acurite manufactured indoor digital humidity and temperature monitor (00325) was used in taking the readings.

3.5.1.3 Moisture Content

The low constant temperature oven method (AOAC, 2007) was used to determine the moisture content of the seeds. Empty glass crucible was thoroughly washed, cleaned and dried for one hour at 130 °C and placed in a desiccator to cool. The empty crucible and its cover were then weighed before and after filling. About 5 g milled soybean seed from each sample was weighed and transferred into a previously weighed empty glass crucible

and placed in an oven maintained at a temperature of 105 °C and dry for 5 h. At the end of the prescribed period, the container was covered and removed from the oven and allowed to cool in a desiccator to room temperature. After cooling, the container with its cover and content was reweighed and figures recorded. Loss in weight was calculated as percentage moisture content (AOAC, 2007).

Calculation of moisture content

$$\% \text{ Moisture (wt)} = \frac{(\text{weight of wet sample} - \text{weight of dry sample}) \times 100}{\text{weight of wet sample}}$$

3.5.1.4 Crude Fat Content

The sample used for the moisture content determination was transferred into a paper thimble, labeled and put in a thimble holder for the crude fat determination. 150 mL of petroleum spirit was poured into a pre-weighed 500 mL round bottom flask and assembled on a semi-continuous soxhlet extractor and refluxed for 16 h. The hexane was recovered after removing the paper thimble from the thimble holder and the flask containing the fat heated for 30 min in an oven at 103^{o}C to get rid of the residual hexane. The flask containing the fat was re-weighed after being cooled in a desiccator (AOAC, 2007). The increase in weight was calculated as percentage crude fat as shown below.

Calculation of fat content

$$\% \text{ Fat} = \frac{\text{(weight of fat)}}{\text{weight of sample}} \times 100$$

3.5.1.5 Protein Content

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

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

Neutralization and Distillation: After the digestion has been completed, the digestion flask was allowed to cool and the solution transferred into a 100 mL volumetric flask and the volume made up to the 100 mL mark with distilled water. The distillation apparatus was flashed out with water and 10 mL of digested sample transferred into the distillation apparatus. The solution was neutralized with 18 mL NaOH and boiled under distillation water in a steam generator. Circulation was allowed for about 10 min. A conical flask was filled with 25 mL 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 10 min and end of condenser washed with distilled water.

Titration: The nitrogen content was then 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 is being analyzed.

Calculation of crude protein content (AOAC, 2007)

$$\%\text{Nitrogen} = \frac{(S_t - S_b) \times NA \times 100 \times 0.1 \times 0.014 \times 100}{\text{Sample weight} \times 10}$$

S_t= Titre of sample

S_b= Titre of blank

NA = Normality of acid

%Protein = % N x F

N= Nitrogen ; F= Factor (6.25)

3.5.2 Seed Health

The blotter method was used to determine the presence or absence of seed borne pathogens (Mathur and Kongsdal, 2001). A sample size of 400 seeds were randomly selected and used for the test. The petri dishes were thoroughly washed and cleaned. The accession number of the seed sample and the date of examination were written on each dish. Three filter papers were used for each dish. The filter papers were dipped in water (distilled or tap water), and when completely wet, raised till the last drop fell before transferring to the dish. Ten (10) seeds were then counted and carefully plated in each dish.

Then all the dishes of a sample were collected in a tray for incubation. The dishes were then incubated for 7 days at 22 ºC under alternating cycles of 12 h darkness and 12 h 1ight (ultraviolet light was used). After incubation, the petri dishes were brought to the examination area in the laboratory. Each seed was examined under a stereomicroscope. The seeds were evaluated on the basis of the vegetative growth, fruiting bodies, and the characteristic symptoms on the seedlings. 'Habit character' was used for the identification of fungi (Mathur and Kongsdal, 2001).

The results were expressed as percentage by number of seeds affected, or as number of organisms in the weight of sample examined (Mathur and Kongsdal, 2001). Data on the number of seeds that were afftected by fungal species were transformed by using Square root transformation. Reporting of results was done on the transformed data.

3.5.3 Germination Percentage

Germination test was carried out to determine the germination percentage of the soybean seeds. 400 seeds from the pure seed fraction of a purity test were used to conduct the germination test. The seeds were arranged in four replications of 100 each on a counting board and planted in a level layer of moist sand in a perforated container and covered.

First count was done on day five (5). On day eight, each replicate was examined and evaluated separately. Seedlings were counted and grouped into normal, abnormal, fresh ungerminated and dead seeds. The percentage germination indicates the proportion of seeds which have produced seedlings classified as normal under the conditions and within the period specified (ISTA, 2007).

Germination % = Number of germinated seeds X 100

Number of total seeds planted

3.5.4 Seed Vigour

Conductivity test was used in determining the vigour of the seeds. The object of a seed vigour test is to provide information about the planting value in a wide range of environment and/or the storage potential of seed lots. Four replicates of 50 seeds of each entry were drawn at random and tested for electrical conductivity. Seeds were placed in Erlenmeyer flasks containing 75 ml ultra pure deionized water equilibrated to 25 °C, then maintained at 25 °C for 24 h. After 24 h of soaking, the flasks was swirled for 10-15 sec and seeds then taken out of water with a clean forcep (ISTA, 2007). An electrical conductivity dip cell was inserted into the seep water until a stabilized reading was achieved and recorded. The mean of the two control flasks (sterilized distilled water) when measured served as background reading. Conductivity was calculated using the formula below (ISTA, 2007).

Conductivity ($\mu S\ cm^{-1}g^{-1}$) = (Conductivity reading - background reading)

(Weight (g) of replicate)

According to Milosevic *et al.* (2010), if the calculated value is < 25 $\mu S\ cm^{-1}g^{-1}$, seed has a high vigour, thus, the seed is suitable for early sowing in unfavourable conditions; 25 –29 $\mu S\ cm^{-1}g^{-1}$, seed can be used for early sowing with risk in unfavourable conditions; 30 – 43 $\mu S\ cm^{-1}g^{-1}$, seed is not suitable for early sowing especially in unfavourable conditions; > 43 $\mu S\ cm^{-1}g^{-1}$, seed has a low vigour i.e.it is not suitable for sowing (Milosevic *et al.*, 2010).

3.6 Data Analysis

Data collected from the field and laboratory experiments were subjected to analysis of variance using Statistix Student Version 9.0. Tukey's HSD (Honest Significant Difference) was used for mean separation at probability level of 0.05 and 0.01 for field and laboratory experiments, respectively.

CHAPTER FOUR

4.0 RESULTS

The research results showing the growth and yield characteristics, the effect of harvesting stages on seed yield and shattering loss of seeds are presented in Tables 4.1 to 4.6. The results from the storage trials on storage condition**,** germinability, vigour (seed conductivity), moisture content, protein and fat content, seed weight and seed health are shown in Tables 4.7 to 4.53.

4.1 Number of days to 50% field emergence and plant height of soybean varieties

Days to 50% field emergence differed significantly (P≤0.05) between the varieties (Table 4.1). Nangbaar emerged on the 7th day whereas both Anidaso and Jenguma emerged on the 9th day. There were also significant differences (P≤0.05) between the varieties, two weeks after planting. Both Jenguma and Nangbaar recorded taller plants than Anidaso. However, at eight and ten weeks after planting, only Jenguma produced significantly taller plants. The shortest plants at 10 WAP were produced by Nangbaar though not significantly different from Anidaso.

Table 4.1: Number of days to 50% field emergence and plant height (cm) of three soybean varieties

Soybean	Days to 50%	Plant Height (cm)				
Varieties	Emergence	2WAP	4WAP	6WAP	8WAP	10WAP
Nangbaar	7	11.01	19.37	31.21	40.38	43.02
Anidaso	9	10.11	19.73	31.48	41.39	44.18
Jenguma	9	11.15	19.79	30.44	43.25	51.29
Mean	8.33	10.76	19.63	31.04	41.67	46.16
Tukey HSD (0.05)	1.22	0.69	1.58	1.37	1.54	2.04

WAP =Weeks After Planting

4.2 Number of branches and number of days to 50% flowering of the varieties

There were significant differences (P≤0.05) between the varieties with regards to the number of branches per plant (Table 4.2). Anidaso registered the highest mean number of branches per plant (8.56) while Jenguma had the least value (7.14).

For the number of days to 50% flowering, significant differences (P≤0.05) were also observed between the varieties. Jenguma was the earliest (46 days) to attain 50% flowering significantly different from Anidaso and Nangbaar which took the longest times of 50 and 51 days, respectively, to attain 50% flowering.

Table 4.2: Number of branches per plant and days to 50% flowering of the three soybean varieties

Soybean Varieties	Number of Branches/Plant	Days to 50% Flowering
Nangbaar	8.10	51
Anidaso	8.56	50
Jenguma	7.14	46
Mean	7.93	49
Tukey HSD (0.05)	0.65	1.14

4.3 Plant yield components and seed purity of three soybean varieties

There were significant differences (P≤0.05) between the varieties with respect to number of pods per plant and number of seed per plant (Table 4.3). Jenguma had the highest mean number of pods per plant (99.62), which differed significantly (P≤0.05) from Anidaso which produced the least (78.73). The number of pods per plant produced by Anidaso was similar to that produced by Nangbaar (83.42). In terms of seeds per plant, Jenguma produced siginficantly the highest number of seeds significantly different from the least by

Nangbaar. Anidaso produced seeds similar in number to that of Nangbaar. As regards purity, there were no significant differences in percentage purity among the varieties (Table 4.3).

Table 4.3: Plant yield components and seed purity of the three soybean varieties

Soybean Varieties	Number of Pods/Plant	Number of Seeds/Plant	% Seed Purity
Nangbaar	83.42	87.53	98.80
Anidaso	78.73	101.02	98.48
Jenguma	99.62	180.73	98.23
Mean	87.26	123.09	98.50
Tukey HSD (0.05)	6.31	15.77	1.09

4.4 Effects of varieties and harvesting stages on seed yield of soybean

There was significant variety x harvesting stage interaction ($P \leq 0.05$) for seed yield such that Jenguma and Nanbgaar each at physiological maturity harvesting stage produced significantly the highest seed yield (Table 4.4). The least seed yield was produced by Nangbaar harvested two weeks after physiological maturiry. For Jenguma, the seed yield produced by harvesting one week after physiological maturity was as good as the Anidaso seed yield harvested at physiological maturity.

Across varieties, harvesting at physiological maturity resulted in the highest seed yield, significantly different from the other harvesting stages. Similarly, harvesting one week after physiological maturity resulted in higher seed yield than harvesting two weeks after physiological maturity (Table 4.4). Also, across harvesting stages, Jenguma variety produced significantly the highest seed yield as compared to Nangbaar and Anidaso which

were similar in their seed yield. Generally, delaying harvesting by one and two weeks after physiological maturity resulted in seed yield loss of 49.4 % and 63.2 %, respectively.

Table 4.4: The effect of harvesting stages of soybean varieties on seed yield (g)

Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	1231.70	904.00	1186.30	1107.33
Harvesting one week after physiological maturity	422.80	503.20	753.50	559.83
Harvesting two weeks after physiological maturity	290.50	349.50	583.20	407.73
Mean	648.33	585.57	841.00	
Tukey HSD (0.05): Variety = 102.28; Harvesting Stages = 102.28; Variety x Harvesting Stages = 244.32.				

4.5 Effects of varieties and harvesting stages on shattering loss of soybean seed

There was no significant variety x harvesting stage interaction for percentage shattering loss of seeds. However, among the varieties, Nangbaar and Anidaso recorded significantly the highest percentage shattering losses of 19.44% and 16.92%, respectively. Jenguma on the contrary had the least shattering loss (14.86%) (Table 4.5).

Among the harvesting stages, varieties harvested at physiological maturity did not encounter any shattering loss, significantly different from the other harvesting stages (Table 4.6). Varieties harvested two weeks after physiological maturity resulted in significantly higher percentage shattering loss (31.22%) than those harvested one week after physiological maturity (20%).

Table 4.5: Percentage shattering loss of three soybean varieties

Soybean Varieties	Percent Shattering loss (%)
Nangbaar	19.44
Anidaso	16.92
Jenguma	14.86
Mean	17.07
Tukey HSD (0.05)	3.89

Table 4.6: Effect of harvesting stages on percentage shattering loss of soybean seeds

Harvesting Stages	% Shattering
Harvesting at physiological maturity	0.00
Harvesting one week after physiological maturity	20.00
Harvesting two weeks after physiological maturity	31.22
Mean	17.07
Tukey HSD (0.05)	3.89

4.6 Ambient conditions of storage environment

Relative humidity ranged from 61.7% to 86.6% whereas temperature ranged between 22.6 ºC and 28.8 ºC. The minimum relative humidity was recorded in January, 2013 and the maximum in June, 2013. The minimum temperature was observed in January, 2013 and the maximum in April, 2013 (Table 4.7).

Table 4.7: Average relative humidity and temperature in the storage environment

Month	Relative Humidity (%)	Temperature (ºC)	Maximum Relative Humidity (%)	Minimum Temperature (ºC)
January	61.68	27.86	66.65	22.61
February	63.37	28.32	80.68	24.46
March	72.82	28.54	83.42	24.77
April	70.10	28.81	84.50	24.77
May	74.19	27.92	86.50	24.16
June	76.21	27.09	86.58	23.85

4.7 Effects of varieties and harvesting stages on germination of soybean seed

There was significant variety x harvesting stage interaction ($P \leq 0.01$) for germination capacity of the seeds (Table 4.8). Nangbaar and Anidaso each at physiological maturity harvesting stage recorded the highest germination percentage (85.25%). Nangbaar harvested two weeks after physiological maturity was as good as Jenguma harvested at physiological maturity. The least seed germination percentage (58.83%) was produced by Jenguma harvested two weeks after physiological maturity (Table 4.8).

Harvesting at physiological maturity stage resulted in high germination percentage, significantly different from the other harvesting stages. Harvesting two weeks after physiological maturity recorded the lowest germination percentage (Table 4.8). Nangbaar variety registered significantly the highest germination percentage (76.61%) as compared to Jenguma which obtained the least (63.42%) (Table 4.8).

Table 4.8: The effect of harvesting stages on germination (%) of soybean seeds

Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	85.25	85.25	66.75	79.08
Harvesting one week after physiological maturity	77.25	68.00	64.67	69.97
Harvesting two weeks after physiological maturity	67.33	60.92	58.83	62.36
Mean	76.61	71.39	63.42	
Tukey HSD (0.01): Variety = 3.82; Harvesting Stages = 3.82; Variety x Harvesting Stages = 8.24.				

4.8 Effects of varieties and storage periods on germination of soybean seed

There was significant variety x storage period interaction ($P \leq 0.01$) for seed germination capacity (Table 4.9). Nangbaar seeds without any storage registered the highest germination percentage (92.17%) though it was not significantly different from other varieties at no storage. Jenguma at six months of storage recorded the lowest germination percentage (34.75%).

Seeds without storage gave significantly the highest germination percentage whereas those stored for six months recorded the least (Table 4.9). Nangbaar had the highest germination percentage of 76.61% while Jenguma obtained the least value of 63.42%

Table 4.9: The effect of storage period on germination (%) of soybean seeds

Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	92.17	86.58	87.33	88.69
Three months of storage	77.75	70.58	68.17	72.17
Six months of storage	59.92	57.00	34.75	50.56
Mean	76.61	71.39	63.42	
Tukey HSD (0.01): Variety = 3.82; Storage Periods = 3.82; Variety x Storage Periods =8.24.				

4.9 Effects of harvesting stages and storage periods on percent germination capacity of soybean seed

Significant harvesting stages x storage periods interaction ($P \leq 0.01$) was observed for germination capacity of soybean seeds (Table 4.10). Harvesting at physiological maturity without seed storage gave significantly the highest germinability (93.75%). This was however similar to seed germination percentage obtained from harvesting one week after physiological maturity without seed storage (90.25%). The lowest germinability was recorded at harvesting two weeks after physiological maturity with six months of seed storage (39.67%).

Harvesting at physiological maturity stage significantly resulted in high germination percentage (79.08%) as compared to harvesting two weeks after physiological maturity which registered the least (62.36%). Seeds without storage obtained significantly the

highest germination percentage than the other storage periods. Similarly, storing soybean seeds for three months resulted in higher germinability than storing for six months (Table 4.10).

Table 4.10: Interaction effect of harvesting stages and storage periods on germination capacity (%) of soybean seeds

Harvesting Stages	Storage Periods			Mean
	No storage	Three months of storage	Six months of storage	
Harvesting at physiological maturity	93.75	79.58	63.92	79.08
Harvesting one week after physiological maturity	90.25	71.58	48.08	69.97
Harvesting two weeks after physiological maturity	82.08	65.33	39.67	62.36
Mean	88.69	72.16	50.56	
Tukey HSD (0.01): Harvesting Stages = 3.82 ; Storage Periods = 3.82; Harvesting Stages x Storage Periods = 8.24				

4.10 Effects of harvesting stages and storage periods on vigour of soybean seed

There were no significant interactions for seed vigour. However, between varieties, Jenguma obtained the highest electrical conductivity value (37.87 μS $cm^{-1}g^{-1}$). Both Anidaso and Nangbaar recorded the lowest (35.20 μS $cm^{-1}g^{-1}$ and 35.56 μS $cm^{-1}g^{-1}$ respectively) though there were no significant differences between them (Table 4.11).

Between the harvesting stages, varieties harvested two weeks after physiological maturity registered significantly the highest conductivity value (40.49 μS $cm^{-1}g^{-1}$) than the other harvesting stages (Table 4.12). Similarly, the electrical conductivity value for varieties

harvested one week after physiological maturity was significantly higher (36.20 μS cm-^{1}g-^{1}) than those harvested at physiological maturity (31.93 μS cm-^{1}g-^{1}).

Between the storage periods, seeds stored for six months recorded significantly the highest conductivity value (47.19 μS cm-^{1}g-^{1}) than other storage periods. Seeds stored for three months also had significantly a higher conductivity value (33.88 μS cm-^{1}g-^{1}) as compared to those without storage (27.55 μS cm-^{1}g-^{1}) (Table 4.13). Generally, seeds stored for three and six months recorded 23 % and 71 % reduction, respectively, in vigour than seeds not stored.

Table 4.11: Seed Conductivity (Vigour) of three soybean varieties

Soybean Varieties	Seed Conductivity (μS cm^{-1}g^{-1})
Nangbaar	35.56
Anidaso	35.20
Jenguma	37.87
Mean	36.21
Tukey HSD (0.01)	2.74

Table 4.12: Effect of harvesting stages on seed conductivity (Vigour) of soybean seeds

Harvesting Stages	Seed Conductivity ($\mu S\ cm^{-1}g^{-1}$)
Harvesting at physiological maturity	31.93
Harvesting one week after physiological maturity	36.21
Harvesting two weeks after physiological maturity	40.49
Mean	36.21
Tukey HSD (0.01)	2.74

Table 4.13: Effect of storage periods on seed conductivity (Vigour) of soybean seed

Storage periods	Seed Conductivity ($\mu S\ cm^{-1}g^{-1}$)
No storage	27.55
Three months of storage	33.88
Six months of storage	47.19
Mean	36.21
Tukey HSD (0.01)	2.74

4.11 Effects of varieties and harvesting stages on moisture content of soybean seed

There was significant variety x harvesting stage interaction ($P \leq 0.01$) for seed moisture content (Table 4.14). Anidaso variety harvested one and two week(s) after physiological maturity produced seeds with the lowest (8.12%) moisture content. The highest seed

moisture content was recorded by Nangbaar harvested one week after physiological maturity stage (8.62%).

Harvesting one week after physiological maturity stage registered significantly high percentage seed moisture content whereas those harvested two weeks after physiological maturity had the lowest (Table 4.14). Across harvesting stages, Anidaso had significantly the lowest seed moisture content of 8.17% while Nangbaar obtained the highest of 8.52%.

Table 4.14: Interaction effects of varieties and harvesting stages on moisture content (%).

Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	8.49	8.28	8.38	8.38
Harvesting one week after physiological maturity	8.62	8.12	8.43	8.39
Harvesting two weeks after physiological maturity	8.44	8.12	8.36	8.31
Mean	8.52	8.17	8.39	
Tukey HSD (0.01): Variety = 0.08; Harvesting Stages = 0.08; Variety x Harvesting Stages = 0.17.				

4.12 Effects of varieties and storage period on moisture content (%) of soybean seed

There was significant variety x storage period interaction (P≤0.01) for seed moisture content (Table 4.15). Anidaso seeds without any storage registered significantly the least (7.55%) moisture content. However, Nangbaar seeds stored for six months had the highest (9.27%) moisture content.

Seeds without storage registered the lowest (7.80%) whereas seeds stored for six months recorded significantly the highest percentage moisture content (9.20%). Anidaso recorded

significantly the least (8.16) percentage moisture content whereas Nangbaar had the highest (8.51) (Table 4.15).

Table 4.15: The effect of storage period on moisture content (%) of soybean seeds

Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	7.99	7.55	7.85	7.80
Three months of storage	8.28	7.79	8.15	8.07
Six months of storage	9.27	9.15	9.17	9.20
Mean	8.51	8.16	8.39	
Tukey HSD (0.01): Variety = 0.08; Storage Periods = 0.08; Variety x Storage Periods = 0.17.				

4.13: Effects of harvesting stages and storage periods on moisture content (%) of soybean seed

There was significant harvesting stages x storage periods interaction ($P \leq 0.01$) for seed moisture content (Table 4.16). Harvesting two weeks after physiological maturity without storage produced significantly the lowest seed moisture content (7.71%). The highest percentage moisture content was obtained by harvesting two weeks after physiological maturity and storing for six months (9.24%).

Harvesting two weeks after physiological maturity had significantly the lowest percentage seed moisture content whereas harvesting one week after physiological maturity stage

recorded the highest (Table 4.16). The least (7.80%) moisture content was recorded for seeds without any storage while seeds stored for six months recorded the highest (9.20%).

Table 4.16: Interaction effect of harvesting stages and storage periods on moisture content (%) of soybean seeds

Harvesting Stages	Storage Periods			Mean
	No storage	Three months of storage	Six months of storage	
Harvesting at physiological maturity	7.82	8.14	9.18	8.38
Harvesting one week after physiological maturity	7.86	8.13	9.18	8.39
Harvesting two weeks after physiological maturity	7.71	7.94	9.24	8.30
Mean	7.80	8.07	9.20	
Tukey HSD (0.01): Harvesting Stages = 0.08; Storage Periods = 0.08; Harvesting Stages x Storage Periods = 0.17				

4.14 Effects of varieties and harvesting stages on protein content of soybean seeds

There was no significant variety x harvesting stage interaction ($P \leq 0.01$) for seed protein content. However, between varieties, Anidaso produced significantly the highest protein content (29.43%) than the other varieties. Jenguma and Nangbaar obtained the lowest protein content 28.78% and 28.91%, respectively (Table 4.17). There was no significant difference between the harvesting stages.

Table 4.17: Protein content of three soyabean varieties

Soybean Varieties	Protein Content (%)
Nangbaar	28.91
Anidaso	29.43
Jenguma	28.78
Mean	29.04
Tukey HSD (0.05)	0.13

4.15 Effects of varieties and storage periods on protein content of soybean seed

There was significant variety x storage period interaction such that Nangbaar and Anidaso stored for six months produced significantly the highest seed protein content (30.51% and 30.40% respectively). The lowest seed protein content was produced by Nangbaar seeds without storage (28.08%) (Table 4.18).

Storing soybean seeds for six months recorded the highest mean percentage protein content (30.14%) while the least was obtained by seeds without storage (28.37%). Across the storage periods, Anidaso produced the highest protein content whereas Jenguma and Nangbaar registered the lowest (Table 4.18)

Table 4.18: Effects of varieties and storage periods on protein content (%) of soybean seeds

Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	28.08	28.68	28.36	28.37
Three months of storage	28.15	29.21	28.45	28.60
Six months of storage	30.51	30.40	29.52	30.14
Mean	28.91	29.43	28.78	
Tukey HSD (0.01): Variety = 0.13; Storage Periods = 0.13; Variety x Storage Periods = 0.28.				

4.16 Effects of harvesting stages and storage periods on protein content (%) of soybean seed.

There was significant harvesting stages x storage periods intereaction ($P \leq 0.01$) for seed protein content (Table 4.19). Harvesting two weeks after physiological maturity and storing seeds for six months gave significantly the highest protein content of 30.28%. The least protein content was recorded by harvesting at physiological maturity without storage (28.31%).

Soybean varieties harvested two weeks after physiological maturity registered high protein content as compared to other harvesting stages, though the difference was not significant (Table 4.19). The lowest protein content was obtained by harvesting at physiological maturity. Seeds stored for six months significantly resulted in high protein content

(30.14%) than other storage periods. Seeds without storage gave the lowest protein content (28.37%) (Table 4.19).

Table 4.19: Effects of harvesting stages and storage periods on protein content (%) of soybean seeds

Harvesting Stages	Storage Periods			Mean
	No storage	Three months of storage	Six months of storage	
Harvesting at physiological maturity	28.31	28.69	30.01	29.00
Harvesting one week after physiological maturity	28.37	28.60	30.13	29.03
Harvesting two weeks after physiological maturity	28.43	28.52	30.28	29.08
Mean	28.37	28.60	30.14	
Tukey HSD (0.01): Harvesting Stages = 0.13; Storage Periods = 0.13; Harvesting Stages x Storage Periods = 0.28				

4.17. Effects of varieties and harvesting stages on oil content of soybean seed

Significant variety x harvesting stage interaction was observed ($P \leq 0.01$) for seed oil content (Table 4.20). Anidaso harvested at physiological maturity stage produced significantly the highest seed oil content (18.61%) whereas Nangbaar harvested one week after physiological maturity recorded the least oil content (18.17%). Harvesting at physiological maturity stage resulted in high seed oil content (18.39%) whilst harvesting two weeks after physiological maturity resulted in the least oil content (18.28%). Anidaso produced the maximum oil content (18.53%). Nangbaar on the other hand obtained the minimum oil content (18.21%) (Table 4.20).

Table 4.20: The effect of harvesting stages and variety on percent seed oil content (%) of soybean

Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	18.22	18.61	18.33	18.39
Harvesting one week after physiological maturity	18.17	18.59	18.28	18.35
Harvesting two weeks after physiological maturity	18.24	18.39	18.21	18.28
Mean	18.21	18.53	18.27	
Tukey HSD (0.05): Variety = 0.05 ; Harvesting Stages = 0.05; Variety x Harvesting Stages = 0.11.				

4.18. Effects of varieties and storage periods on oil content of soybean seed

There was significant variety x storage period interaction for seed oil content (Table 4.21). Anidaso seed without storage contained significantly the highest oil content (18.63%) whereas Nangbaar and Jenguma seeds stored for six months contained the lowest oil content (18% and 18.06% respectively). Soybean seeds without storage contained significantly high oil content (18.61%) as compared to seeds stored for six months which recorded the least (18.17%). Anidaso had the highest oil content (18.53%). Nangbaar registered the least oil content (18.21%).

Table 4.21: The effect of storage periods on oil content (%) of soybean seeds

Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	18.59	18.63	18.61	18.61
Three months of storage	18.04	18.53	18.14	18.24
Six months of storage	18.00	18.44	18.06	18.17
Mean	18.21	18.53	18.27	
Tukey HSD (0.05): Variety = 0.05 ; Harvesting Stages = 0.05; Variety x Storage Periods = 0.11.				

4.19: Effects of harvesting stages and storage periods on oil content of soybean seed

There was no significant harvesting stages x storage periods interaction for seed oil content. However, between harvesting stages, harvesting at physiological maturity gave significantly the highest oil content (18.39%) (Table 4.22). The least oil content was obtained by harvesting two weeks after physiological maturity (18.28%). Between storage periods, the highest oil content was produced by seeds without storage (18.61%) whilst the lowest was recorded by seeds stored for six months (18.17%) (Table 4.23).

Table 4.22: Effect of harvesting stages on oil content of soybean seed

Harvesting Stages	Oil Content (%)
Harvesting at physiological maturity	18.39
Harvesting one week after physiological maturity	18.34
Harvesting two weeks after physiological maturity	18.28
Mean	18.34
Tukey HSD (0.01)	0.05

Table 4.23: Effect of storage periods on oil content of soybean seed

Storage periods	Oil Content (%)
No storage	18.61
Three months of storage	18.24
Six months of storage	18.17
Mean	18.34
Tukey HSD (0.01)	0.05

4.20 Main effects of varieties, harvesting stages, storage periods on 1000 seed weight of soybean seed

There were no significant interactions for one thousand seed weight. However, among varieties, Jenguma registered significantly the heaviest seed weight (126.30 g). The least seed weight was obtained by Nangbaar and Anidaso (116.92 g and 116.97 g, respectively (Table 4.24).

Between harvesting stages, harvesting at physiological maturity had significantly the maximum seed weight (126.24 g). On the contrary, harvesting two weeks after physiological maturity led to minimum weight (115.52 g) (Table 4.25). Between storage periods, seeds stored for six months obtained significantly the highest seed weight (124.29 g) as compared to other storage periods. Similarly, seeds stored for three months significantly recorded a high seed weight (119.14 g) than those without storage (116.76 g) (Table 4.26).

Table 4.24: 1000 seed weight (g) of soybean as affected by varieties.

Soybean Varieties	Seed Weight (g)
Nangbaar	116.92
Anidaso	116.97
Jenguma	126.30
Mean	120.10
Tukey HSD (0.01)	2.29

Table 4.25: Effect of harvesting stages on 1000 seed weight of soybean seed

Harvesting Stages	1000 Seed Weight (g)
Harvesting at physiological maturity	126.24
Harvesting one week after physiological maturity	118.43
Harvesting two weeks after physiological maturity	115.52
Mean	120.06
Tukey HSD (0.01)	2.29

Table 4.26: The effect of storage periods on 1000 seed weight (g) of soybean seeds.

Soybean Varieties	Seed Weight (g)
No storage	116.76
Three months of storage	119.14
Six months of storage	124.29
Mean	120.10
Tukey HSD (0.01)	2.29

4.21 Effects of harvesting stages and varieties on *Aspergillus flavus* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Aspergillus flavus* (Table 27). Nangbaar harvested one week after physiological maturity recorded the heaviest load of *Aspergillus flavus*, significantly greater than the other treatment combinations but similar to that of Anidaso harvested at two weeks after physiological maturity. The least load of *Aspergillus flavus* was recorded by Jenguma harvested one week after physiological maturity (Table 4.27).

Harvesting two weeks after physiological maturity resulted in the highest mean incidence of *Aspergillus flavus* (7.70) as compared to harvesting one week after physiological maturity which had the least (7.47) (Table 4.27). Nangbaar variety registered the highest incidence (8.19) of *Aspergillus flavus* while Jenguma recorded the least (7.18).

Table 4.27: The effect of harvesting stages and varieties on *Aspergillus flavus* load on seed of soybean.

Aspergillus flavus				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	7.91	6.98	7.86	7.58
Harvesting one week after physiological maturity	8.69	6.96	6.76	7.47
Harvesting two weeks after physiological maturity	7.97	8.22	6.92	7.70
Mean	8.19	7.39	7.18	
Tukey HSD (0.01): Variety = 0.23; Harvesting Stages = 0.23; Variety x Harvesting Stages = 0.50.				

4.22 Effects of storage periods and varieties on *Aspergillus flavus* load on soybean seed

There was significant variety x storage period interaction for the incidence of *Aspergillus flavus*. The highest load (9.79) of *Aspergillus flavus* was recorded by Nangbaar seeds stored for six months, though was not significantly different from other varieties at six months of storage. Jenguma seeds stored for three months had the least (5.96).

Soybean seeds stored for six month registered the heaviest load of *Aspergillus flavus*, significantly different from seeds stored for three months which had the least. However, seeds without storage and seeds stored for three months were similar and not significantly different from each other (Table 4.28). Nangbaar recorded significantly the highest (8.19) incidence of *Aspergillus flavus* whereas Jenguma had the lowest (7.18) (Table 4.28).

Table 4.28: The effect of storage periods and varieties on *Aspergillus flavus* load on seed of soybean.

Aspergillus flavus				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	7.38	6.41	6.08	6.62
Three months of storage	7.41	6.41	5.96	6.59
Six months of storage	9.79	9.34	9.50	9.54
Mean	8.19	7.39	7.18	
Tukey HSD (0.01): Variety = 0.23; Storage Periods = 0.23; Variety x Storage Periods = 0.50.				

4.23 Effects of harvesting stages and varieties on *Aspergillus niger* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Aspergillus niger* (Table 4.29). Nangbaar and Jenguma harvested two weeks after physiological maturity had the heaviest load of *Aspergillus niger*. Nangbaar harvested one week after physiological maturity however obtained the least load of *Aspergillus niger* (Table 4.29).

Harvesting two weeks after physiological maturity had the maximum incidence of *Aspergillus niger* (4.07) whereas harvesting at physiological maturity had the minimum (2.23). Across harvesting stages, Jenguma and Anidaso obtained a high incidence of *Aspergillus niger*. Nangbaar registered the minimum incidence of *Aspergillus niger* (Table 4.29).

Table 4.29: The effect of harvesting stages and varieties on *Aspergillus niger* load on seed of soybean.

Aspergillus niger				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	1.90	2.10	2.69	2.23
Harvesting one week after physiological maturity	1.48	4.39	2.77	2.88
Harvesting two weeks after physiological maturity	4.46	3.29	4.45	4.07
Mean	2.61	3.26	3.30	
Tukey HSD (0.01): Variety = 0.28; Harvesting Stages = 0.28; Variety x Harvesting Stages = 0.60.				

4.24. Effects of varieties and storage periods on *Aspergillus niger* load on soybean seed

Significant variety x storage period interaction was observed for the incidence of *Aspergillus niger*. Jenguma seeds stored for three months registered significantly a high load (4.02) of *Aspergillus niger*. However, Jenguma stored for six months recorded the lowest load (2) of *Aspergillus niger* (Table 4.30).

Storing soybean seeds for three months recorded significantly the highest incidence (3.50) of *Aspergillus niger*, whereas seeds stored for six months had the lowest (2.32). The heaviest load of *Aspergillus niger* was recorded by Jenguma (3.33) and was significantly different from Nangbaar which had the lowest (2.62) (Table 4.30).

Table 4.30: The effect of storage periods and varieties on *Aspergillus niger* load on seed of soybean.

Aspergillus niger				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	2.60	3.61	3.88	3.36
Three months of storage	2.89	3.58	4.02	3.50
Six months of storage	2.36	2.59	2.00	2.32
Mean	2.62	3.26	3.33	
Tukey HSD (0.01): Variety = 0.28; Storage Periods = 0.28; Variety x Storage Periods = 0.60.				

4.25 Effects of harvesting stages and varieties on *Botryodiplodia theobromae* load on soybean seed

There was significant variety x storage period interaction for the incidence of *Botryodiplodia theobromae*. Nangbaar harvested one week after physiological maturity and Jenguma harvested two weeks after physiological maturity recorded significantly the highest incidence of *Botryodiplodia theobromae.* Anidaso in all the three harvesting stages had the lowest of *Botryodiplodia theobromae* incidence (Table 4.31).

Harvesting two weeks after physiological maturity obtained the highest value (0.79) of *Botryodiplodia theobromae* incidence whilst harvesting one week after physiological maturity had the least (0.77), though the difference was not significant. Nangbaar had significantly the highest (0.84) load of *Botryodiplodia theobromae* while Anidaso obtained the lowest (0.71) (Table 4.31).

Table 4.31: The effect of harvesting stages and varieties on *Botryodiplodia theobromae* load on seed of soybean

Botryodiplodia theobromae				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	0.84	0.71	0.79	0.78
Harvesting one week after physiological maturity	0.88	0.71	0.71	0.77
Harvesting two weeks after physiological maturity	0.79	0.71	0.88	0.79
Mean	0.84	0.71	0.79	
Tukey HSD (0.01): Variety = 0.07; Harvesting Stages = 0.07; Variety x Harvesting Stages = 0.15.				

4.26 Effects of varieties and storage periods on *Botryodiplodia theobromae* load on soybean seed

Significant variety x storage period interaction was observed for the incidence of *Botryodiplodia theobromae* (Table 4.32). Nangbaar seeds stored for six months had significantly the maximum incidence of *Botryodiplodia theobromae*. Anidaso in all the storage periods had the minimum incidence (Table 4.32).

Soybean seeds stored for six months registered a high incidence (0.93) of *Botryodiplodia theobromae*. Seeds without storage and seeds stored for three months had the least (0.71). *Botryodiplodia theobromae* incidence was high (0.84) in Nangbaar as compared to Anidaso which recorded the lowest (0.71) (Table 4.32).

Table 4.32: The effect of storage periods and varieties on *Botryodiplodia theobromae* load on seed of soybean

Botryodiplodia theobromae				
Storage Periods	Soyabean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	0.71	0.71	0.71	0.71
Three months of storage	0.71	0.71	0.71	0.71
Six months of storage	1.10	0.71	0.97	0.93
Mean	0.84	0.71	0.80	
Tukey HSD (0.01): Variety = 0.07; Storage Periods = 0.07 Variety x Storage Periods = 0.15.				

4.27 Effects of varieties and harvesting stages on *Curvularia geniculata* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Curvularia geniculata*. The heaviest load (4) of *Curvularia geniculata* was recorded for Jenguma harvested two weeks after physiological maturity. Nangbaar in all the three harvesting stages had the least load (0.71) of *Curvularia geniculata*.

Harvesting two weeks after physiological maturity registered significantly high mean value (1.93) of *Curvularia geniculata*. Harvesting at physiological maturity and one week after physiological maturity resulted in the least load (0.71). Across harvesting stages, the highest incidence of *Curvularia geniculata* was recorded by Jenguma whilst Nangbaar had the lowest (Table 4.33).

Table 4.33: The effect of harvesting stages and varieties on *Curvularia geniculata* load on seed of soybean

Curvularia geniculata				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	0.71	0.71	0.71	0.71
Harvesting one week after physiological maturity	0.71	0.71	0.71	0.71
Harvesting two weeks after physiological maturity	0.71	1.07	4.00	1.93
Mean	0.71	0.83	1.81	
Tukey HSD (0.01): Variety =0.08; Harvesting Stages = 0.08; Variety x Harvesting Stages = 0.17.				

4.28 Effects of varieties and storage periods on *Curvularia geniculata* load on soybean seed

There was significant variety x storage period interaction for the incidence of *Curvularia geniculata* (Table 4.34). The heaviest load (2.37) was registered by Jenguma seeds without storage. Nangbaar in all the storage periods had the lowest load (0.71) of *Curvularia geniculata*.

Soybean seeds without storage and those stored for three months had the maximum incidence (1.32) of *Curvularia geniculata* as compared to those that were stored for six months (0.71). Jenguma obtained the highest (1.81) incidence of *Curvularia geniculata* while Nangbaar had the least (0.71) (Table 4.34).

Table 4.34: The effect of storage periods and varieties on *Curvularia geniculata* load on seed of soybean

Curvularia geniculata				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	0.71	0.87	2.37	1.32
Three months of storage	0.71	0.91	2.34	1.32
Six months of storage	0.71	0.71	0.71	0.71
Mean	0.71	0.83	1.81	
Tukey HSD (0.01): Variety = 0.08; Storage Periods = 0.08; Variety x Storage Periods = 0.17.				

4.29 Effects of varieties and harvesting stages on *Cercospora kikuchii* load on soybean seed

There was significant variety x harvesting stage interaction for *Cercospora kikuchii* incidence. Anidaso harvested two weeks after physiological maturity recorded the highest load of *Cercospora kikuchii* (2.35) as compared to Jenguma which registered the lowest (0.71) in all the three harvesting stages (Table 4.35)

The highest load of *Cercospora kikuchii* was observed at harvesting two weeks after physiological maturity (1.31). Harvesting at physiological maturity had the least value (0.74) and the difference was significant. *Cercospora kikuchii* incidence was high (1.26) in Anidaso but low in Jenguma (0.71).

Table 4.35: The effect of harvesting stages and varieties on *Cercospora kikuchii* load on seed of soybean

Cercospora kikuchii				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	0.79	0.71	0.71	0.74
Harvesting one week after physiological maturity	0.91	0.71	0.71	0.78
Harvesting two weeks after physiological maturity	0.88	2.35	0.71	1.31
Mean	0.86	1.26	0.71	
Tukey HSD (0.01): Variety = 0.09; Harvesting Stages = 0.09; Variety x Harvesting Stages = 0.19.				

4.30 Effect of varieties and storage periods and on *Cercospora kikuchii* load on soybean seed

There was significant variety x storage period interaction for *Cercospora kikuchii* incidence (Table 4.36). Anidaso seeds stored for three months resulted in high incidence (1.30) of *Cercospora kikuchii*. Jenguma had the lowest incidence (0.71) in all the storage periods. Higher incidence of *Cercospora kikuchii* was observed in seeds stored for six months (1.04) as compared to those without storage which had the least (0.88). Anidaso registered a high incidence (1.25) of *Cercospora kikuchii* while Jenguma obtained the lowest (0.71) (Table 4.36).

Table 4.36: The effect of storage periods and varieties on *Cercospora kikuchii* load on seed of soybean

Cercospora kikuchii				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	0.71	1.21	0.71	0.88
Three months of storage	0.71	1.30	0.71	0.91
Six months of storage	1.17	1.25	0.71	1.04
Mean	0.86	1.25	0.71	
Tukey HSD (0.01): Variety = 0.09; Variety x Storage Periods = 0.09; Variety x Storage Periods = 0.19.				

4.31 Effects of varieties and harvesting stages on *Cladosporium sphaerospermum* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Cladosporium sphaerospermum* (Table 4.37). The highest load of *Cladosporium sphaerospermum* was recorded by Anidaso harvested one week after physiological maturity (7.90). The least was noted in Jenguma harvested two weeks after physiological maturity (4.94)

Harvesting one week after physiological maturity had significantly the highest incidence of *Cladosporium sphaerospermum* (7.08) whilst harvesting two weeks after physiological maturity obtained the least value (6.54). Anidaso registered significantly the highest incidence (7.63) of *Cladosporium sphaerospermum* whereas Jenguma variety recorded the least (6.01).

Table 4.37: The effect of harvesting stages and varieties on *Cladosporium sphaerospermum* load on seed of soybean

Cladosporium sphaerospermum				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	6.32	7.12	6.58	6.67
Harvesting one week after physiological maturity	6.81	7.90	6.52	7.08
Harvesting two weeks after physiological maturity	6.80	7.87	4.94	6.54
Mean	6.64	7.63	6.01	
Tukey HSD (0.01): Variety = 0.18; Harvesting Stages = 0.18; Variety x Harvesting Stages = 0.39.				

4.32 The effect of storage periods and varieties on *Cladosporium sphaerospermum* load on seed of soybean

There was significant variety x storage period interaction for the incidence of *Curvularia geniculata* (Table 4.38). Nangbaar seeds stored for three months had significantly the highest load (9.66) of *Cladosporium sphaerospermum*. However, the least was noted in Nangbaar seeds stored for six months (0.71).

The degree of incidence of *Cladosporium sphaerospermum* was significantly high in seeds without storage (9.18) than seeds stored for six months (2.01). *Cladosporium sphaerospermum* incidence was high in Anidaso (7.63) as compared to other varieties. Jenguma on the other hand recorded the least (6.01).

Table 4.38: The effect of storage periods and varieties on *Cladosporium sphaerospermum* load on seed of soybean

Cladosporium sphaerospermum				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	9.57	9.49	8.47	9.18
Three months of storage	9.66	9.41	8.21	9.09
Six months of storage	0.71	3.98	1.35	2.01
Mean	6.65	7.63	6.01	
Tukey HSD (0.01): Variety = 0.18; Storage Periods = 0.18; Variety x Storage Periods = 0.39.				

4.33 The effect of harvesting stages and varieties on *Cercospora sesame* load on seed soybean

There was significant variety x harvesting stage interaction for the incidence of *Cercospora sesame* (Table 4.39). The heaviest load of *Cercospora sesame* (3.87) was noted in Jenguma harvested two weeks after physiological maturity. The least load (0.71) was observed in Nangbaar in all the harvesting stages.

Harvesting two weeks after physiological maturity obtained significantly the highest incidence (2.44) of *Cercospora sesame* whereas harvesting at physiological maturity had the least mean value (0.71). Jenguma variety had the highest significant value (6.14) of *Cercospora sesame*. Nangbaar on the contrary recorded the least (0.71).

Table 4.39: The effect of harvesting stages and varieties on *Cercospora sesame* load on seed of soybean

Cercospora sesame				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	0.71	0.71	0.71	0.71
Harvesting one week after physiological maturity	0.71	0.71	1.56	0.99
Harvesting two weeks after physiological maturity	0.71	2.73	3.87	2.44
Mean	0.71	1.38	6.14	
Tukey HSD (0.01): Variety = 0.16; Harvesting Stages = 0.16; Variety x Harvesting Stages = 0.34.				

4.34 Effects of varieties and storage periods on *Cercospora sesame* load on soybean seed

There was significant variety x storage period interaction for the incidence of *Cercospora sesame* (Table 4.40). Jenguma seeds stored for three months had a high incidence (2.76) of *Cercospora sesame*. The lowest (0.71) was however noted in Nangbaar in all the storage periods.

Seeds without storage registered significantly the highest mean value (1.75) of *Cercospora sesame* incidence, whereas seeds stored for six months had the least (0.71). Jenguma recorded a high incidence (2.05) of *Cercospora sesame* while Nangbaar registered the minimum (0.71).

Table 4.40: The effect of storage periods and varieties on *Cercospora sesame* load on seed of soybean

Cercospora sesame				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	0.71	1.86	2.67	1.75
Three months of storage	0.71	1.58	2.76	1.68
Six months of storage	0.71	0.71	0.71	0.71
Mean	0.71	1.38	2.05	
Tukey HSD (0.01): Variety = 0.16; Storage Periods = 0.16; Variety x Storage Periods = 0.34.				

4.35 Effects of harvesting stages and varieties on *Fusarium moniliforme* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Fusarium moniliforme* (Table 4.41). The heaviest load (6.29) of *Fusarium moniliforme* was noted in Nangbaar harvested two weeks after physiological maturity, significantly different from Anidaso harvested two weeks after physiological maturity which recorded the least (3.78).

The maximum incidence of *Fusarium moniliforme* was recorded at harvesting one week after physiological maturity (6.20) and the difference was significant. Harvesting two weeks after physiological maturity obtained the minimum (4.88). Nangbaar variety had significantly the highest incidence (5.90) of *Fusarium moniliforme* whilst Anidaso had the least (5.09) (Table 4.41).

Table 4.41: The effect of harvesting stages and varieties on *Fusarium moniliforme* load on seed of soybean

Fusarium moniliforme				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	5.15	5.43	5.17	5.25
Harvesting one week after physiological maturity	6.26	6.06	6.28	6.20
Harvesting two weeks after physiological maturity	6.29	3.78	4.56	4.88
Mean	5.90	5.09	5.34	
Tukey HSD (0.01): Variety = 0.29; Harvesting Stages = 0.29; Variety x Harvesting Stages = 0.62.				

4.36 The effect of storage periods and varieties on *Fusarium moniliforme* load on soybean seed

There was significant variety x storage period interaction for the incidence of *Fusarium moniliforme* (Table 4.42). Nangbaar seeds without any storage obtained significantly the highest incidence (7.96) of *Fusarium moniliforme*. The least (1.23) was noted in Anidaso stored for six months. Soybean seeds without storage had significantly a higher load (7.42) of *Fusarium moniliforme* as compared to those stored for six months (1.80). *Fusarium moniliforme* incidence was significantly high in Nangbaar (5.90) but low in Anidaso seeds (5.09).

Table 4.42: The effect of storage periods and varieties on *Fusarium moniliforme* load on seed of soybean

Fusarium moniliforme				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	7.96	7.05	7.24	7.42
Three months of storage	7.60	7.00	6.76	7.12
Six months of storage	2.15	1.23	2.01	1.80
Mean	5.90	5.09	5.34	
Tukey HSD (0.01): Variety = 0.29; Storage Periods = 0.29; Variety x Storage Periods = 0.62.				

4.37 The effect of harvesting stages and varieties on *Fusarium pallidoroseum* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Fusarium pallidoroseum* (Table 4.43). *Fusarium pallidoroseum* incidence was significantly high (5.87) in Anidaso variety harvested two weeks after physiological maturity. Jenguma harvested at physiological maturity recorded the least (1.47).

The highest significant incidence of *Fusarium pallidoroseum* was observed at harvesting two weeks after physiological maturity (4.14) whereas harvesting at physiological maturity had the least (1.98). Anidaso variety registered significantly a higher incidence of *Fusarium pallidoroseum* (4.27). Nangbaar variety recorded the least incidence of *Fusarium pallidoroseum* (2.30).

Table 4.43: The effect of harvesting stages and varieties on *Fusarium pallidoroseum* load on seed of soybean

Fusarium pallidoroseum				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	2.83	2.63	1.47	1.98
Harvesting one week after physiological maturity	1.83	4.32	1.94	2.70
Harvesting two weeks after physiological maturity	2.23	5.87	4.32	4.14
Mean	2.30	4.27	2.58	
Tukey HSD (0.01): Variety = 0.26; Harvesting Stages = 0.26; Variety x Harvesting Stages = 0.57.				

4.38 Effects of storage periods and varieties on *Fusarium pallidoroseum* load on soybean seed

There was significant variety x storage period interaction for the incidence of *Fusarium pallidoroseum* (Table 4.44). Higher incidence of *Fusarium pallidoroseum* was noted in Anidaso (4.45) seeds stored for three months whilst Nangbaar seeds stored for six months obtained the lowest (1.30).

Fusarium pallidoroseum incidence was high in seeds without storage (3.35), but was low for seeds stored for six months (2.47). The heaviest load was noted in Anidaso (4.28), significantly different from Nangbaar which had the lowest (2.30).

Table 4.44: The effect of storage periods and varieties on *Fusarium pallidoroseum* load on seed of soybean

Fusarium pallidoroseum				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	2.82	4.33	2.90	3.35
Three months of storage	2.77	4.45	2.77	3.33
Six months of storage	1.30	4.05	2.05	2.47
Mean	2.30	4.28	2.57	
Tukey HSD (0.01): Variety = 0.26; Storage Periods = 0.26; Variety x Storage Periods = 0.57.				

4.39 Effects of harvesting stages and varieties on *Phoma lingam* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Phoma lingam* (Table 4.45). Anidaso harvested one week after physiological maturity obtained significantly the highest incidence (1.27) of *Phoma lingam.* Both Nangbaar and Jenguma had the lowest incidence (0.71) of *Phoma lingam* in all the harvesting stages.

Harvesting one week after physiological maturity recorded significantly a higher incidence (0.90) of *Phoma lingam*. Harvesting at physiological maturity registered the minimum incidence of *Phoma lingam* (0.77). The highest load was observed in Anidaso (1.02), significantly different from Both Nangbaar and Jenguma which recorded the least (0.71) (Table 4.45)

Table 4.45: The effect of harvesting stages and varieties on *Phoma lingam* load on seed of soybean

Phoma lingam				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	0.71	0.88	0.71	0.77
Harvesting one week after physiological maturity	0.71	1.27	0.71	0.90
Harvesting two weeks after physiological maturity	0.71	0.91	0.71	0.78
Mean	0.71	1.02	0.71	
Tukey HSD (0.01): Variety = 0.06; Harvesting Stages = 0.06; Variety x Harvesting Stages = 0.12.				

4.40 The effect of storage periods and varieties on *Phoma lingam* load on seed of soybean

There was significant variety x storage period interaction for the incidence of *Phoma lingam* (Table 4.46). *Phoma lingam* incidence was significantly high (1.28) in Anidaso seeds stored for six months. Both Nangbaar and Jenguma obtained the lowest (0.71) in all the storage periods.

The incidence of *Phoma lingam* was high in seeds stored for six months (0.90) as compared to seeds without storage (0.75). Anidaso had significantly the highest incidence (1.02). Nangbaar and Anidaso registered the lowest (0.71) (Table 4.46)

Table 4.46: The effect of storage periods and varieties on *Phoma lingam* load on seed of soybean

Phoma lingam				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	0.71	0.84	0.71	0.75
Three months of storage	0.71	0.94	0.71	0.79
Six months of storage	0.71	1.28	0.71	0.90
Mean	0.71	1.02	0.71	
Tukey HSD (0.01): Variety = 0.06; Storage Periods = 0.06; Variety x Storage Periods = 0.12.				

4.41 Effects of harvesting stages and varieties on *Penicillium spp* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Penicillium spp* (Table 4.47). The highest incidence (3.91) of *Penicillium spp* was observed in Jenguma harvested one week after physiological maturity whereas Anidaso at the same harvesting stage recorded the least (2.48).

Harvesting two weeks after physiological maturity registered a higher incidence (3.09) of *Penicillium spp* whilst seeds harvested at physiological maturity had the least (2.83). Jenguma variety obtained significantly the highest (3.13) incidence of *Penicillium spp.* Nangbaar recorded the least (2.89) of *Penicillium spp.*

Table 4.47: The effect of harvesting stages and varieties on *Penicillium spp* load on seed of soybean

Penicillium spp				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	2.86	2.90	2.74	2.83
Harvesting one week after physiological maturity	2.79	2.48	3.91	3.06
Harvesting two weeks after physiological maturity	3.01	3.51	2.74	3.09
Mean	2.89	2.96	3.13	
Tukey HSD (0.01): Variety = 0.17; Harvesting Stages = 0.17; Variety x Harvesting Stages = 0.37.				

4.42 Effects of storage periods and varieties on *Penicillium spp* load on soybean seed

There was significant variety x storage period interaction for the incidence of *Penicillium spp* (Table 4.48). Nangbaar seeds stored for six months had significantly a high incidence of *Penicillium spp* (6.95). However, Nangbaar seeds without storage registered the lowest mean (0.79).

Penicillium spp incidence was high in seeds stored for six months (6.52) but low with seeds without storage (1.17). The highest (3.13) significant incidence was noted in Jenguma variety. The least was observed in Nangbaar (2.88).

Table 4.48: The effect of storage periods and varieties on *Penicillium spp* load on seed of soybean

Penicillium spp				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	0.79	1.44	1.27	1.17
Three months of storage	0.91	1.63	1.35	1.30
Six months of storage	6.95	5.82	6.78	6.52
Mean	2.88	2.96	3.13	
Tukey HSD (0.01): Variety = 0.17; Storage Periods = 0.17; Variety x Storage Periods = 0.37.				

4.43 Effects of harvesting stages and varieties on *Macrophomina phaseolina* load on seed of soybean

There was significant variety x harvesting stage interaction for the incidence of *Macrophomina phaseolina*, Nangbaar and Anidaso variety harvested at physiological maturity recorded significantly the highest incidence (2.07 and 1.94 respectively) of *Macrophomina phaseolina*. Jenguma variety harvested one week after physiological maturity registered the lowest incidence (0.92) (Table 4.49).

Harvesting at physiological maturity had the highest incidence (1.69) of *Macrophomina phaseolina*. In contrast, harvesting one week after physiological maturity had the least (1.05). Among varieties, the highest incidence (2.09) of *Macrophomina phaseolina* was noted in Anidaso while the lowest was observed in Nnagbaar (1.49)

Table 4.49: The effect of harvesting stages and varieties on *Macrophomina phaseolina* load on seed of soybean

Macrophomina phaseolina				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	2.07	1.94	1.07	1.69
Harvesting one week after physiological maturity	0.95	1.28	0.92	1.05
Harvesting two weeks after physiological maturity	1.44	1.12	1.83	1.46
Mean	1.49	2.09	1.27	
Tukey HSD (0.01): Variety = 0.20; Harvesting Stages = 0.20; Variety x Harvesting Stages = 0.43.				

4.44 Effects of storage periods and varieties on *Macrophomina phaseolina* load on soybean seed

There was no significant variety x storage period interaction for the incidence of *Macrophomina phaseolina*. However, between varieties, the highest incidence of *Macrophomina phaseolina* was registered by Nangbaar while the least was recorded by Jenguma (Table 4.50). Between the storage periods, seeds stored for three months had significantly the highest (1.82) incidence of *Macrophomina phaseolina* while seeds stored for six months obtained the least (0.71) (Table 4.51).

Table 4.50: *Macrophomina phaseolina incidence* on soybean varieties

Soybean Varieties	*Macrophomina phaseolina* incidence
Nangbaar	1.49
Anidaso	1.45
Jenguma	1.27
Mean	1.40
Tukey HSD (0.01)	0.20

Table 4.51: The effect storage periods on *Macrophomina phaseolina* load on soybean seeds

Soybean Varieties	*Macrophomina phaseolina* incidence
No storage	1.69
Three months of storage	1.82
Six months of storage	0.71
Mean	1.41
Tukey HSD (0.01)	0.20

4.45 Effects of harvesting stages and varieties on *Rhizopus spp* load on soybean seed

There was significant variety x harvesting stage interaction for the incidence of *Rhizopus spp*. Anidaso harvested two weeks after physiological maturity recorded significantly the highest (1.33) incidence of *Rhizopus spp*. Both Nangbaar and Jenguma recorded the least (0.71). The highest load of *Rhizopus spp* was observed in harvesting two weeks after physiological maturity, significantly different from harvesting one week after physiological maturity (Table 4.52). Anidaso had significantly the highest load of *Rhizopus spp*. Nangbaar and Jenguma registered the least load of *Rhizopus spp* (Table 4.52).

Table 4.52: The effect of harvesting stages and varieties on *Rhizopus spp* load on seed of soybean

Rhizopus spp				
Harvesting Stages	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
Harvesting at physiological maturity	0.71	1.11	0.71	0.84
Harvesting one week after physiological maturity	0.71	0.96	0.71	0.79
Harvesting two weeks after physiological maturity	0.71	1.33	0.71	0.92
Mean	0.71	1.13	0.71	
Tukey HSD (0.01): Variety = 0.09 ; Harvesting Stages = 0.09; Variety x Harvesting Stages = 0.20.				

4.46 Effects of storage periods and varieties on *Rhizopus spp* load on soybean seed

There was significant variety x storage period interaction for the incidence of *Rhizopus spp* (Table 4.53). Anidaso seeds stored for six months had the highest (1.63) *Rhizopus spp* incidence. Nangbaar and Jenguma obtained the least (0.71) in all the three storage periods.

Soybean seeds stored for six months had significantly a high incidence (1.02) of *Rhizopus* than seeds which were not stored (0.76). *Rhizopus spp* incidence was significantly high (1.14) in Anidaso but low (0.71) in Nangbaar and Jenguma varieties.

Table 4.53: The effect of storage periods and varieties on *Rhizopus spp* load on seed of soybean

Rhizopus spp				
Storage Periods	Soybean Varieties			Mean
	Nangbaar	Anidaso	Jenguma	
No storage	0.71	0.87	0.71	0.76
Three months of storage	0.71	0.91	0.71	0.78
Six months of storage	0.71	1.63	0.71	1.02
Mean	0.71	1.14	0.71	
Tukey HSD (0.01): Variety = 0.09; Storage Periods = 0.09; Variety x Storage Periods = 0.20.				

CHAPTER FIVE

5.0 DISCUSSION

5.1 Growth characteristics of the soybean varieties

Nangaar emerged earlier than both Anidaso and Jenguma. According to Adu-Dapaah *et al.* (2005), Nangbaar has a very good field emergence. Asafo-Adjei *et al.* (2005) also indicated that Nangbaar is an early maturing variety, Anidaso is medium maturing and Jenguma late maturing. Therefore, the inherent or genotypic character in Nangbaar contributed in making it emerge earlier than the two other varieties. Adu-Dapaah *et al.* (2005) reported that Nangbaar grows to a height of 42 cm while Denwar and Mohammed (2008) recorded average plant height of 65 cm for Jenguma. Earlier, Onwueme and Sinha (1991) indicated that soybean cultivars range in height from 45 – 120 cm. All cultivars used for this experiment fell into this range.

Anidaso had the greatest number of branches per plant whereas Jenguma had the least. Nangbaar had an average number of 8.10 branches per plant. Adu-Dapaah *et al.* (2005) pointed out that Nangbaar bears an average of 6 branches per plant which makes the results of the present study slightly higher than what they reported. The reason could be due to environmental differences in the two studies since branching has been found to be dependent on environmental conditions (Onwueme and Sinha, 1991).

At the reproductive stage, the numbert of days to 50% flowering in the present study for Jenguma, Nangbaar and Anidaso at Fumesua corroborated earlier reports at the same location by Adu-Dapaah *et al.* (2005) and Denwar and Mohammed (2008).

5.2 Pod and seed yield performance of the three soybean varieties

The number of pods per plant differed among the varieties. Jenguma recorded the highest number of pods per plant while Anidaso had the least. Furthermore, Jenguma recorded the highest number of seeds per plant. Jenguma also obtained the highest seed yield as compared to Nangbaar and Anidaso. The finding of the present study is in agreement with Asafo-Adjei *et al.* (2005) who reported higher grain yields for Jenguma (1.7 – 2.8 tons/ha) than for both Nangbaar (1.5 – 2.5 tons/ha) and Anidaso (1.2 -1.8 tons/ha).

The results also revealed that harvesting at physiological maturity had the highest seed yield in all the varieties whilst harvesting two weeks after physiological maturity recorded the lowest yield. These findings confirmed the report of Vasudevan *et al.* (2008) that harvesting of the seed crop at physiological maturity is better as seeds will be having maximum dry weight, higher viability and vigour, besides higher seed yield and yield attributing parameters. Boudreaux and Griffin (2008) also stated that leaving soybean plants in the field past maturity exposes seed to adverse weather conditions that can reduce yield and quality. Moreover, the research findings revealed that if soybean harvesting is delayed by one and two weeks after physiological maturity, seed yield loss of 49.4% and 63.2%, are likely to be encountered by producers.

The present study also showed that the degree of shattering loss of seeds varied among varieties. Whereas Jenguma recorded the least shattering loss of seeds, Nangbaar and Anidaso lost a significantly higher percentage. In terms of stage of maturity, none of the varieties harvested at physiological maturity experienced shattering loss of seeds. This is in contrast to the same varieties harvested one and two weeks after physiological maturity which encountered significantly higher shattering losses especially in Nangbaar and

Anidaso. The present study also revealed that delaying harvesting by one and two weeks after physiological maturity resulted in 20 and 31.22% shattering loss, respectively, of the total seed weight. According to Asafo-Adjei *et al.* (2005), if soybean is left on the field after the pods are dry, the seeds may shatter, especially in the north where the dry harmattan winds can speed up the shattering process. Harvesting too late may increase the risk of shattering and decrease the quality of seeds due to ageing (Ellis and Pieta Filho, 1992; Wang *et al.*, 2008). But for some of the newly released varieties such as Jenguma that has a low shattering character, losses in yield from delayed harvesting may be attributable to other causes (SARI, 2012).

5.3 The effect of harvesting and storage period on seed physical qualities

All the three varieties were found to have high percentage purity levels which implied that the seeds were properly cleaned after harvesting. van-Gastel *et al.*(1996) stated that farmers require seeds which are uncontaminated with seed of different crop species or weeds, or inert matter (straw, soil, etc.) that may reduce the quality of their product. This quarantees that farmers buy seeds of the required species and not inert matter (stones, chaff, etc.) and dangerous weeds or parasitic weeds (*Orobanche, Cascuta, and Striga*) (van-Gastel *et al.*, 1996).

The results showed that 1000 seed weight of varieties harvested two weeks after physiological maturity was low as compared to those harvested at physiological maturity. Conversely, for all the varieties, the 1000 seed weight of six month-old seed was higher than that which was not stored and could be attributed to the rise in relative humidity in every month in storage.

In this experiment, Nangbaar had an average 1000 seed weight of 116.92 g, Anidaso had 116.97 g and Jenguma, 126.30 g. Adu-Dapaah *et al.* (2005), found the average 1000 seed weight for Nangbaar to be 115.5±7.2 g, 96.08±8.2 g for Anidaso. The result for Nangbaar was similar to that of Adu-Dapaah *et al.* (2005). However, that of Anidaso differed from what Adu-Dapaah *et al.* (2005) reported. ISTA (2007) established that the object of 1000 seed weight was to determine the weight per 1000 seeds of the sample submitted which was useful for calculating the sowing or planting rate of all seeds marketed according to weight, since large sized and heavy seeds require a higher planting rate to produce the same plant population as small-sized and light seed.

5.4 The effect of harvesting stage of soybean and storage period on seed chemical content

According to van-Gastel *et al.* (1996), since moisture content influences seed quality during harvesting, processing and storage, it should be kept low at all stages. High moisture content at harvest damages the seed coat, whereas during storage, it initiates fungal development, insect activity, heating and germination, which contribute to rapid seed deterioration. However, low moisture content makes seed liable to mechanical damage during harvesting and processing (van-Gastel *et al.*, 1996).

The results of the present study indicated that the seed moisture content for the entire storage duration ranged between 7.55 and 9.27. These figures were within the safe moisture limit for long storage and implied that the seeds were dried properly before storage. Daun (1995) recommended that oilseeds storage for extended period is only possible if the seed moisture content is less than 10 % or preferably dried to 8 %.

In addition, the experimental results showed that the moisture content increased in response to an increase in the storage duration under ambient conditions. The climatic information during the study period revealed that there was a rise in relative humidity from January to June. Therefore, the seeds absorbed moisture under ambient storage. Nevertheless, the rise in moisture content did not exceed the safe moisture limit.

Nangbaar had an average protein content of 28.91%, Anidaso had 29.4% and Jenguma obtained 28.8%. Adu-Dapaah *et al.* (2005) found the average protein content of Nangbaar at physiological maturity to be 43.00±0.18% and 46.38±0.08% for Anidaso. This implied that the average percentage protein content obtained from this study was low as compared to the findings of Adu-Dapaah *et al.* (2005). The results also showed that the percentage protein content increased periodically in storage. However, according to Bothast (1978), the total protein content of seed as calculated from its nitrogen content is generally assumed to be constant during storage. As fungal deterioration advances however and carbohydrate is used in the respiratory processes, protein increases when protein test is conducted and calculated.

In the present study, it was revealed that seeds harvested at physiological maturity recorded the highest percentage oil content while those harvested two weeks after physiological maturity had the lowest. At physiological maturity, Nangbaar recorded an oil content of 18.22%, Anidaso had 18.61%, and Jenguma obtained 18.33%. Adu-Dapaah *et al.* (2005) recorded an average fat content of 16.77±0.23% for Nangbaar and 16.45±0.07% for Anidaso at physiological maturity. The implication was that the fat content obtained in this study was comparatively high to that of Adu-Dapaah *et al.* (2005). However, it confirmed the findings of Sauvant *et al*. (2004) that at maturity, soybean contains 18% oil.

Furthermore, the results also revealed that as the storage duration increased, the oil content reduced. According to Kausar *et al*. (2009), oil seeds are very sensitive to the harsh environmental conditions. It is hypothesized that their oil content readily oxidizes, which enhances deterioration of the seed in storage. Therefore, the reduction could be attributed to oxidation during storage. According to Balesevic-Tubic *et al*. (2007), the chemical composition of oilseeds causes specific processes to occur during storage. The seeds rich in lipids have limited longevity due to their specific chemical compostion. For example, soybean seed storage demands special attention due to its oil content, otherwise processes may occur that would lead to the loss of germination ability and seed viability (Balesevic-Tubic *et al*., 2007). Shrinking and breaking of seeds during storage are some of the physical changes that occurred in soybean seed in storage (Narayan *et al*., 1988a).

5.5 The effect of harvesting stages and storage duration on seed health of soybean varieties

Irrespective of the varieties, harvesting stages or storage periods, a total number of thirteen fungal species were identified on the three soybean varieties. These included *Aspergillus flavus*, *Aspergillus niger*, *Botryodiplodia theobromae*, *Curvularia geniculata*, *Cercospora kikuchii*, *Cladosporium sphaerospermum*, *Cercospora sesame*, *Fusarium moniliforme*, *Fusarium pallidoroseum*, *Macrophomina phaseolina*, *Phoma lingam*, *Penicillium spp*, *Rhizopus spp*. Shelar *et al.* (2008) indicated that a large number of pathogens is associated with soybean seed which leads to the reduction in germination and storability of the seed. However, Agarwal (1995) pointed out that seed borne microflora association with seed does not necessarily result in disease condition.

According to Agrios (2005), for a disease to occur, the three components (host, pathogen and environment) must come into contact and interact. If any of the three components is zero, there can be no disease. As one component changes, it affects the degree of disease severity within the host (Agrios, 2005).

Neergaard (1979) earlier stated 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. This implies that one of the most important components of pathogens to cause disease is the inoculum. Though the pathogens were identified in all the varieties, at the three harvesting stages and three storage periods but their percentage inoculums level did not exceed economic injury level to cause economic damage or disease condition in seed quality especially before storage and three months of storage. However, after six months of storage, these pathogenic fungi species contributed to reducing the quality of the seed particularly germinability and vigour.

5.6 Effect of stage of harvest and storage period on germinability and vigour of soybean varieties

Soybean varieties harvested at physiological maturity recorded the highest germination percentage while those harvested two weeks after physiological maturity had the lowest. Current findings confirmed the report by Vasudevan *et al.* (2008) that harvesting of the seed crop at physiological maturity is better as seeds will be having maximum dry weight, higher viability and vigour, besides higher seed yield and yield attributing parameters (Vasudevan *et al.*, 2008). Mahesha *et al.* (2001) also added that at physiological maturity, seed shall have maximum viability and vigour.

In relation to the storage period (Table 4.9), it was observed that germinability percentage decreased when the period of storage increased. However, the decline in seed germination at six months of storage was more pronounced under ambient conditions. The results indicated that the soybean seed was significantly more sensitive to the length of storage, as well as the storage conditions. Similar results were obtained by Nugraha and Soejadi (1991) for soybean seed stored for six months under conventional conditions. They stated that in a group of tested varieties only one maintained germination above 80%.

This also confirmed the findings of Shelar and Shaikh (2002), who stated that irrespective of genotypes, the germination potential of soybean seeds decreased during storage. Shelar *et al.* (2008) also added that the germination potential (viability) is very short lived in soybean as compared to other oilseed crops and are often reduced prior to planting time. This loss of germination is much more acute under tropical conditions. These environmental conditions make it very difficult to maintain viability during storage.

It was also observed from the study that seeds harvested two weeks after physiological maturity recorded the highest conductivity values in all the varieties while those harvested at physiological maturity had the least values (Table 4.12). However, ISTA (2007) indicated that seed lots that have high electrolyte, that is, having high leachate conductivity, are considered as having low vigour, whilst those with low leakage (low conductivity) are considered high vigour seeds. This implies that seeds harvested at physiological maturity were more vigourous and had good seed coat intergrity than seeds harvested one and two weeks after physiological maturity. This explains why germinability was high in varieties harvested at physiological maturity than those harvested one and two weeks after physiological maturity. Further, among varieties, Jenguma recorded the highest conductivity value than both Nangbaar and Anidaso.

These results also highlight the reason why germination percentage was low in Jenguma but high in Nangbaar and Anidaso.

In addition, seeds stored for six months recorded significantly the highest conductivity value as compared to other storage periods. This implies that seed vigour decreased when the period of storage increased. At the beginning of seed storage, the vigour was high in all the varieties but reduced as time progressed, especially, at six months of storage. This support the statement made by Nkang and Umho (1996) that one of the major constraints to the production of soybean in the tropics is the rapid loss of seed viability and vigour during storage under ambient conditions. Pratt *et al*. (2009) added that as seed quality deteriorates during storage, vigour declines before loss in standard germination.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The research findings from the field experiment indicated that Nangbaar emerged earlier than Anidaso and Jenguma. However, Jenguma flowered earlier than the two. Jenguma at tenth week after planting significantly produced taller plants as compared to Nangbaar which produced shortest plants. Jenguma produced greater number of pods and seeds per plant over Anidaso and Nangbaar. Among the varieties, Jenguma had the highest seed yield while Anidaso recorded the least. Soybean varieties harvested at physiological maturity had no shattering loss and high seed yield as compared to the other harvesting stages. Seed yield of soybean decreased with increasing delay in harvesting.

One thousand seed weight and percentage moisture content increased under ambient storage conditions. The oil content of the seeds reduced in storage while the protein content increased. Irrespective of the varieties, harvesting stages and storage periods, thirteen fungal species were identified on the three soybean varieties. These seed borne fungal species contributed to reducing the quality of the seeds (particularly germinability and vigour) after six months of storage. Moreover, soybean varieties harvested at physiological maturity registered a high germination percentage and vigour than those harvested one and two weeks after physiologicl maturity. Temperature and relative humidity were high and fluctuated under ambient storage conditions. These conditions also contributed to reducing seed quality.

6.2 Recommendations

1. Soybean seed should be harvested at physiological maturity, since it has comparative advantage over other harvesting stages.
2. Storage time should be extended beyond six months to assess the effect of long term storage on seed quality characteristics.
3. Various packaging materials should be investigated to determine the role packaging plays in extending seed quality in storage under ambient conditions.
4. The present study should be repeated in other agro-ecological zones to determine the role of environment on seed quality and subsequent field performance.

REFERENCES

1. **Acasio, A. (2010)**. Handling and storage of soybeans and soybean meal. *International Journal Plant Production,* Vol. 53 (4): pp. 41-50.
2. **Addai, I.K. and Safo- Kantanka, O. (2006)**. Evaluation of Screening Methods for Improved Storability of Soybean Seed. *International Journal of Botany,* 2: 152-155.
3. **Adu-Dapaah, H., Asibuo, J.Y., Danquah, O.A. and Adusei-Akowuah, P. (2000).** Introduction and Evaluation of Exotic Germplasm. CSIR-CRI Annual Report. Pg 89.
4. **Adu-Dapaah, H.K., Asibuo J.Y., Asafo-Adjei. B., Dashiel, K., Amoah, S., Asafu-Adjei, J.N. and Addo, J.K. (2005).** *Breeding Methodology, Botanical and Agronomic Characteristics of four Groundnut, Two Cowpea and two Soybean Genotypes Proposed for Release.* Pp. 42-60.
5. **Akubor, P.I. and Ukwuru, M.U. (2005).** Functional properties and biscuit making potential of soybean and cassava flour blends. *Plant Foods for Human Nutrition,*58(3): 1-12.
6. **Agarwal, R. L. (1995).** *Seed Technology.* Second Edition. Oxford and IBH Publishing Co. Pvt LTD. India. 829 pp.
7. **Agrios, G. N. (2005)**. *Plant Pathology*. Fifth Edition. Elsevier Academic Press, Oxford, UK. Pp 79-103.
8. **AOAC International. (2007).** Official methods of analysis,18th edn., 2005; Current through revision 2, 2007 (Online). AOAC International, Gaithersburg, MD.

9. **Asafo-Adjei, B., Ansah I.O.O., Asuboah, R.A., Dapaah, H., Harruna M., and Oti-Boateng, C. (2005)**. CSIR (CRI and SARI) and MOFA. *Soybean Production Guide*.

Food Crops Development Project, Ghana. Pp 1-39.

10. **Balešević-Tubić, S., Malenčić, Đ., Tatić, M. and Miladinović, J., (2005)**. Influence of aging process on biochemical changes in sunflower seed. *Helia* 28(42): 107-114.

11. **Balesevic-Tubic, S., Tatic, M., Hrustic, M., Miladinovic, J., Maksimovic, L., (2007).** The influence of aging process on germination and seedling growth of sunflower seed. In: Proceedings of the First Joint PSU-UNS International Conference on BioScience: Food, Agriculture, and the Environment, Thailand: 198-202.

12. **Bankole, S. A., Osho, A., Joda, A. O. and Einkuomenhin, O. A. (2005).** Effects of drying method on the quality and storability of 'egusi' melon seeds (*Cococynthis citrullus* L.). *African Journal of Biotechnology,* Vol.4 (8) Pp799.

13. **Basu, R. N. (1995)**. Seed Viability. In. Seed Quality: Basic Mechanisms and Agricultural Implications. Amarjit, S. Basra (Eds). Food Products Press. An Imprint of the Haworth PressInc. New York, London, Norwood (Australia). Pp 1-5.

14. **Bothast, R. J. (1978)**. *Fungal Deterioration and Related Phenomena in Cereals, Legumes and Oilseeds.* U. S. Department of Agriculture, Peoria, IL 61604. Pp. 210 – 226.

15. **Boudreaux, J. M. and Griffin, J. L. (2008).** Harvest aids in indeterminate and determinate soybeans—application timing and value. Louis. Agri 51:26–27. Cited from: Application Timing of Harvest Aid Herbicides Affects Soybean Harvest and Yield. Boudreaux, J. M. and J. L. Griffin (2011). *Weed Technology*, 25(1):38-43.

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

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

18. **Copeland, L. O. and McDonald, B. M. (2001)**. *Principles of Seed Science and Technology.* Technology and Engineering. 4th Edition. Chapman and Hall, New York. Pp 201- 214.

19. **Copeland, L. O. and McDonald, B. M. (1995).** Seed viability testing. In principles of seed science and technology (3rdEd). Chapman and Hall, New York. Pp 111-126.

20. **Dadson, R.B. and Noureldin, N.A. (Eds.). (2001).** *Soybeans in Egypt, Research, Production, Economics, Nutrition and Health.* University Press of Maryland, Bethesda, Maryland. 3-27.

21. **Daun, J. K. (1995).** Seed Analysis. In: *Brassica Oilseeds. Production and Utilization.* (Eds) D.S. Kimber and McGregor, D. I. CAB international. Pp 245.

22. **Delouche, J.C., Matthens, R.K., Dougherty, G.M. and Boyd, A.H. (1973).** Storage of seed in sub-tropical and tropical regions. *Seed Sci. Technol.* 1: 633-692.

23. **Delouche, J. C. (1980).** Evironmental effects on seed development and seed quality, *Hort. Sci.*, 15: 775-780.

24. **Demir. I., Ashirov, A. M. and Mavi. K. (2008).** Effect of seed production environment and time of harvest on Tomato (*Lycopersicon esculentum*) seedling growth. *Res. J. Seed. Sci.*, 1: 1-10.

25. **Demir, I., Mavi, K. Sermenli, T. and Ozcoban, M. (2002).** Seed development and maturation in Aubergine (Solanum melongena L.). *Gartenbanwissenschaft*, 67:148-154.

26. **Denwar, N. N. and Mohammed, H. (2008).** Development of soybean varieties of early, medium and late maturing groups. CSIR-SARI Annual Report, 2008. Pp 11.

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

28. **Elias, S.G. and Copeland, L.O. (1994)**. The effect of storage conditions on canola (*Brassica napus* L.) seed quality. *Journal of Seed Technology* 18: 21-22.

29. **Elias, S., Garay, A. and Gatch, E. (2011).** Seed Quality Testing and Certification: Resources Useful in Organic Seed Production. *Organic Seed Resource Guide article.* Oregon State University and Washington State University, USA.

30. **Ellis, R. H. (1992).** Seed and seedling vigour in relation to crop growth and yield. *Plant Growth Regulation Journal*, 11: 249-255. Department of Agriculture, University of Reading, Earley Gate, UK. Kluwer Academic Publishers.

31. **Ellis, R.H and Pieta-Filho, C. (1992).** Seed development and cereal seed longevity, *Seed. Sci. Res.*, 3: 247-257.

32. **Eskandari, H. (2012).** Seed Quality Variation of Crop Plants during Seed Development and Maturation. *International journal of Agronomy and Plant Production*, Vol., 3 (11), 557-560, 2012.

33. **Fabrizius, E., Tekroni, D. M., Egli, D. B. and Rucker, M. (1999).** Evaluation of viability model for prediction soybean seed germination during warehouse storage. *Crop Science*, 39: 194-201.

34. **FAO. (2010).** FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy.

35. **FAO. (2010).** Seeds in Emergencies: A Technical Handbook. FAO Plant Production and Protection Paper 202, Rome, Italy.

36. **FAO/UNESCO legend (1986).** Technical Paper1. Soil classification and characteristization. Food and Agriculture Organization of the United Nations, Rome, Italy. The United Nations Educational, Scientific and Cultural Organization, Place de Fontenoy, Paris, France.

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

Freistritzer, W.P., Vock, H. A., Kelly, F. and Ziger, E. K. (Eds). FAO. Rome. Pp 3, 33-43, 51-53.

38. **Gokhale, D. (2009).** Post harvest Seed Storage/handling. Syngenta Foundation for Sustainable Agriculture. STAK Conference, Nairobi. Pp. 1-11.

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

40. **Hans, K., Fjell, L.D. and Kilgore, G.L. (1997).** Seed Bed Preparation and Planting Practices: Soybean Production Handbook. Kansas State University, Kansas, pp: 8. Quoted from: Evaluation of Screening Methods for Improved Storability of Soybean Seed. Addai, I.K.and O. Safo- Kantanka (2006). *International Journal of Botany, 2: 152-155.*

41. **Harington, J. F. (1972).** Seed storage and longevity, In: *Seed Biology*. Kozlowski TT (Ed.). Academic Press, New York. Pp. 145-245.

42. **Hegstad, H.G. (2008).** Nutritional and Health benefits of Soybean. Soy Protein Quality Evaluation Report, Food and Agriculture Organization of the United Nations, Food and Nutrition Paper No. 71, Rome, Italy.

43. **Hong, T.D. and Ellis. R. H. (1996).** Desiccation Tolerance and Potential Longevity of

Developing Seeds of rice (*Oryza sativa*). *Ann.Bot.*73:501-506.

44. **Hurburgh, C.R., Charles, R., Elmore R. and Pedersen, P. (2007).** Frost Damage to Corn and Soybeans. Iowa State University Extension. *Online. https://www.extension.iastate.edu/Publications/PM1635.pdf*

45. **Indira, K. and C. Dharmalingam (1996).** Seed development and maturation in fenugreek, Madras. *Agric. J.*, 83: 239-240.

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

47. **Kandel, H. (Ed.). (2010).** *Soybean Production.* North Dakota State University, Fargo, Norht Dakota. Pp. 128 – 142.

48. **Kausar M., Mahmood, T. Basra, S.M.A. and Arshad, M. (2009).** Invigoration of low vigor sunflower hybrids by seed priming. *Int. J. Agric. Biol.* 11: 521-528.

49. **Keller, M. and Kollmann, J. (1999).** Effects of seed provenance on germination of herb for agricultural Compensation, sited. *Agric. Ecosystem. Environ.*, 72: 87-99.

50. **Khaliliaqdam, N., Soltani, A., Latifi, N. and Far, F. G. (2012).** Quantitative Response of Soybean Seed under Controlled Conditions. *American –Eurasian J. Agric. & Environ. Sci.*, 12(2): 224-230.

51. **Khatun, A., Kabir, G. and Bhuiyan, M. A. H. (2009).** Effect of harvesting stages on the seed quality of Lentil (*Lens culinaris* L.) during storage. *Bangladesh J. Agric. Res.* 34(4) : 565-576.

52. **Kure, O. A., Bahago, E.J. and Daniel, E.A. (1998).** Studies on the proximate composition and effect of flour particle size of acceptability of biscuits production from blends of soyabeans and plantain flours. *Namoda Tech. Scop J.* 3(2): 17-22.

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

54. **Lu Quanyu. (1984).** An Overview of the Present State of Controlled Atmosphere Storage of Grain in China. In: *Controlled Atmosphere and Fumigation in Grain Storages*.

55. **Malenčić, Đ., Popović, M. and Miladinović, J. (2003).** Stress tolerance parameters in different genotypes of soybean. *Biology Plantarum* 46: 141-143.

56. **Mahesha, C. R., Channaveeraswami, A. S., Kurdikeri, M. B., Shekhargouda, M. and Merwade, M. N. (2001).** Seed maturation studies in sunflower genotypes. *Seed Res.* 29(1): 95-97.

57. **Marcos-Filho, J., Chamma, H. M. C. P., Casagrande, J.R. R. and Marcos, E.A. (1994).** Effect of harvesting time on seed physiological quality, chemical composition and storability of soybeans. *Sci. agric., Piracicaba,* 51(2); 298-304.

58. **Mathur, S. B., Njala, M. and Kongsdal, O. (2003).** *An Illustration Handbook on Normal and Abnormal Seedlings of Tropical and sub-Tropical Crops.* Danish Government Institute of Seed Pathology for Developing Countries. Thorvaldsenwej 57; 1871 Fredriksberg C. Copenhagan, Denmark. Pp 1-15.

59. **Mathur, S. B. and Kongsdal, O. (2001).** Common Laboratory Seed Health Testing Methods for detecting Fungi. First Edition. Danish Government Institute of Seed Pathology for Developing Countries, Copenhagen, Denmark. 95-104.

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

61. **McCormack, H. J. (2004).** Seed Processing and Storage. Principles and Practices of Seed harvesting and storage: An organic seed production manual for seed growers in the mid-Atlantic and Southern US. Pp. 9-17.

62. **Miloševic, M. and Maleševic, M. (2004).** *Seed*. Institute of Field and Vegetable Crops, Novi Now: 110-114.

63. **Miloševic M., Vujakovic, M. and Karagic, D. (2010).** Vigour tests as indicators of seed viability. *Genetika*, Vol 42, No. 1, 103 -118.

64. **Narayan, R., Chauhan, G. S. and Verma, N. S. (1988a).** Changes in the quality of soybean during storage. Part 1- Effect of storage on some physic-chemical properties of soybean. *Food Chemistry*, Vol. 27, No.1, pp. 12-23.

65. **Narayan, R., Chauhan, G. S. and Verma, N. S. (1988b).** Changes in the quality of soybean during storage. Part 2- Effect of soybean storage on the sensory qualities of the products made there from. *Food Chemistry*, Vol. 30, No.3, pp. 181-190.

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

67. **Nkang, A. and Umho, E. O. (1996).** Six month storability of five soybean cultivars as influenced by stage of harvest, storage temperature and relative humidity. *Seed Science and Technol.*, 25: 93-99.

68. **Nkang, A. and Umoh, E.O. (1997)**. Six month storability of five soybean cultivars as influenced by stage of harvest, storage temperature and relative humidity. *Seed Sci. and Technol.* 25:93-99.

69. **Nugraha, U.S. and Soejadi, S. (1991)**. Evaluation on seed storability on soybean genotypes. *Indon. J. Crop Sci.* 6: 1-10.

70. **O'Brien, R.D. (2004).** *Fats and Oil Formulating and Processing for Applications*, CRC Press, Boca Raton, United States.

71. **Onwueme, I. C. and Sinha, T. D. (1991).** *Field Crop Production in Tropical Africa Principles and Practice.* Technical Centre for Agricultural and Rural Co-operation (CTA), Netherlands. Pp. 337 – 342**.**

72. **Padin, S., Bello, G. D. and Fabrizio, M. (2002).** Grain loss caused by *Tribolium castaneum, Sitophilus oryzae* and *Acanthoscelides obtectus* in stored durum wheat and beans treated with *Beauveria bassiana. Journal of Stored Products Research,* Vol. 38, No.1, pp. 69-74.

73. **Perry, D A. (1982).** The influence of seed vigour on vegetable seedling establishment. *Sci. Hort.* 33: 67–75.

74. **Philbrook, B. D. and E. S. Oplinger.** (1989). Soybean field losses as influenced by harvest delays. *Agron. J* 81:251–258.

75. **Pratt, P., Bolin, P. and Godsey, C. (Eds.). (2009).** *Soybean Production Guide*. Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University. Pp. 12-114.

76. **Rasyad, D. A., Van Sanfors, D. A., Tekrony, D. M. (1990).** Changes in seed viability and vigour during wheat seed maturation. *Seed Sci. Technol.* 18: 25p9-267.

77. **Sanhewe, A.J. and Ellis, R.H. (1996).** Seed development and maturation in *Phaseolus vulgaris*. II. Post-harvest longevity in air-dry storage. *J. Exp. Bot.*, 47: 959-965.

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

79. **SARI (2012).** *Soybean: A production guide for northern Ghana*. Alliance for a Green Revolution in Africa Soil Health Project, 2009 SHP 005. Pp. 4-7.

80. **Sauvant, D., Perez, J. M., and Tran, G. (Ed.). (2004).** Tables of composition and nutritional value of feed materials, *INRA*, France. Quoted from: Fatty Acid Composition of Various Soybean Products. Ivanov D. S., J. D. Lević, and S. A. Sredanović. *Journal of the Institute for Food Technology in Novi Sad, Bulevar cara Lazara 1, Serbia*.

81. **Sharma, H. C. (1998).** Bionomics, host plant resistance, and management of the legume pod borer, Maruca vitrata: a review. *Crop Protection* 17, 373-386.

82. **Shelar, V. R. (2007).** Strategies to Improve the Seed Quality And Storability of Soybean – A Review. Seed Technology Research Unit (NSP), Mathtme Phule Krighi Vidyprth, Rahuri 413- 722, India. *Agricultural Review, 28 (3):* 188-196, 2007.

83. **Shelar, V.R. and Shaikh, N. (2002).** Soybean seed quality during storage. Seed Technology research. *Agricultural Review, 29 (2):*125-131.

84. **Shelar, V. R., Shaikh, R. S. and Nikam, A. S. (2008).** Soybean Seed Quality During Storage: A Review. *Agric. Rev.*, 29 (2): 125 – 131.

85. **Shewry, P.R., Miles, M.J. and Tatham, A. S. (1993).** The prolamin storage proteins of wheat and related species. Prog. Biophys. *Molecular Biology*. 61: 37-59

86. **Shu, Q.Y. (2012).** Pyramiding of mutated genes contributing to crop quality & resistance to stress affecting quality. Joint FAO/IAEA.

87. **Sidibe, A., Watson, C. E., Cabreba, E. R. and Keith, B. (1999).** Group IV Soybean Seed Qualty as affected by planting and harvesting date in the Mississippi Delta in 1996. *Mississippi Agricultural and Forestry Experiment Station. Bulletin 1084.*

88. **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.

89. **Sinclair, J.B. (1995).** Re-evaluation of grading standards and discounts for fungus-damaged soybean seeds. *Journal of the American Oil Chemists' Society.* Vol.72, No.12, pp. 1415-1419.

90. **Singh, G. (Ed.). (2010).** *The Soybean: Botany, Production and Uses.* CAB International. Pp. 1-10.

91. **Singh, S. R. and Jackai, L. E. N. (1988).** The legume pod-bearer, *Maruca testulalis* (Geyer): past, present and future research. *Insect Science and its Applications* 9, 1-5.

92. **Singh, S.R., Jackai, L. E. N., Dos Santos, J.H.R. and Adalla, C.B. (1990).** Insect pests of cowpea. pp.43-90. In: Singh, S.R. (Ed) *Insect Pests of Tropical Food legumes*. Chichester, UK, John Wiley and Sons.

93. **Sisman, C., and Delibas, L. (2004).** Storing sunflower seed and quality losses during storage. *Journal of Central European Agriculture*, 4: 239-250.

94. **Tekrony, D. M., Hunter, J. L. (1995).** Effect of seed maturation and genotype on seed vigour in maize. *Crop Sci*., 35: 857-862.

95. Tekrony D.M., Egli, D., Balles, D. B., Stuky, J. and Tomas L. (1984). Effect of date of harvest maturity on soybean seed quality and phomopsis sp. Seed infection. *Crop Sci.* 14: 189-193.

96. UNIFEM. (1994). *Cereal Processing*. Intermediate Technology Publication Ltd, 103 – 105. Southampton, ROW, London. WC.1B 4 H H, UK. Pp. 10.

97. University of Greenwich. (1999). Grain Storage Management PG Dip/MSc Computer Mediated Distance Learning Course 1.Storage and Handling- Volume 2. Univ. of Greenwich Central Avenue Chatham Maritime Kent Me4 4TB, UK. Pp. 134- 162.

98. Usberti, R., Roberts, E. H. and Ellis, R. H. (2006). Prediction of cottonseed longevity. *Pesq. Agropec.bras., Brasilia*, 41: 1435-1441.

99. USDA. (2010). World Soybean Production 2010.
Online at *http://www.soystats.com/2011/page_30.htm*

100. Van-Eys, J. E., Offner, A. and Bach, A. (2004). Manual of Quality Analyses for Soybean Products in the Feed Industry, *American Soy-bean Association United Soybean Board*, USA.

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

102. Vasudevan, S. N., Sudarshan, J. S. Kurdikeri, M. B. Dharmatti, P. R. (2008). Influence of Harvesting stages on Seed Yield and Quality in Fenugreek. *Karnataka J.* Agric. Sci., 21 (1) : (122-124).

103. Venter, H. A, Demir, I., Meillon, S. and Loubser, S. (1996). Seed development and maturation in edible dry bean (Phaseolus vulgaris L.) cv. 'Teebus'. *South. African. J. Plant. Soil*. 13(2): 47–50.

104. Wang, Y., Mu, C., Hou, Y. and Li, X. (2008). Optimum harvest time of *Vicia cracca* in relation to high seed quality during pod development. *Crop Sci.*, 48: 709-715.

105. Wehrmann, V.K., Fehr, W.R., Cianzio, S.R. and Cavins, J.F. (1987). Transfer of high seed protein to high-yielding soybean cultivars. *Crops Science*, Vol. 27, Pp. 927-931.

106. Wicklow, T. D. (1995). The Mycology of Stored Grain: An ecological Perspective. In: *Stored-Grain Ecosystems*. (Eds) Digrir, S. Jayas, Noel D. G. White and William E. Muir. Marcel Decker Incorporated, New York. Pp197-205.

107. Wilcox, J. F. and Calvin, J. F. (1992). Normal and low linolenic acid soybean strains: Response to planting date. *Crop Science.* 32:1248-1251.

108. 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.

APPENDIX

Analysis of Vartiance

Fact A = Varieties
Fact B = Harvesting Stages
Fact C = Storage Periods

Growth and Yield Data

Analysis of Variance Table for Days to Fifty Percent Emergence

Source	DF	SS	MS	F	P
Block	2	9.073	4.536		
Fact_A	2	24.0000	12.0000	12.00	0.0007
Fact_B	2	0.22222	0.11111	0.11	0.8955
Fact_A*Fact_B	4	1.77778	0.44444	0.44	0.7748
Error	16	16.0000	1.00000		
Total	26	42.0000			

Grand Mean 8.3333 CV 12.00

Analysis of Variance Table for Plant Height at Week 2

Source	DF	SS	MS	F	P
Block	2	0.2462	0.12308		
Fact_A	2	5.7078	2.85388	8.96	0.0024
Fact_B	2	0.0229	0.01147	0.04	0.9647
Fact_A*Fact_B	4	0.0138	0.00346	0.01	0.9997
Error	16	5.0946	0.31841		
Total	26	11.0853			

Grand Mean 10.755 CV 5.25

Analysis of Variance Table for Plant Height at Week 4

Source	DF	SS	MS	F	P
Block	2	2.2214	1.11068		
Fact_A	2	0.9437	0.47185	0.28	0.7603
Fact_B	2	0.0839	0.04194	0.02	0.9756
Fact_A*Fact_B	4	1.1780	0.29450	0.17	0.9485
Error	16	27.0746	1.69216		
Total	26	31.5016			

Grand Mean 19.631 CV 6.63

Analysis of Variance Table for Plant Height at Week 6

Source	DF	SS	MS	F	P
Block	2	46.9105	23.4552		
Fact_A	2	5.3081	2.6541	2.09	0.1566
Fact_B	2	1.7136	0.8568	0.67	0.5238
Fact_A*Fact_B	4	3.6556	0.9139	0.72	0.5916
Error	16	20.3521	1.2720		
Total	26	77.9399			

Grand Mean 31.043 CV 3.63

Analysis of Variance Table for Plant Height at Week 8

Source	DF	SS	MS	F	P
Block	2	250.645	125.322		
Fact_A	2	38.159	19.079	11.98	0.0007
Fact_B	2	3.983	1.991	1.25	0.3128
Fact_A*Fact_B	4	3.545	0.886	0.56	0.6973
Error	16	25.476	1.592		
Total	26	321.808			

Grand Mean 41.673 CV 3.03

Analysis of Variance Table for Plant Height at Week 10

Source	DF	SS	MS	F	P
Block	2	185.533	92.767		
Fact_A	2	360.508	180.254	64.02	0.0000
Fact_B	2	1.238	0.619	0.22	0.8051
Fact_A*Fact_B	4	0.818	0.205	0.07	0.9895
Error	16	45.053	2.816		
Total	26	593.150			

Grand Mean 46.163 CV 3.64

Analysis of Variance Table for Number of Branches per Plant

Source	DF	SS	MS	F	P
Block	2	0.6756	0.33778		
Fact_A	2	9.3356	4.66778	16.27	0.0001
Fact_B	2	0.1422	0.07111	0.25	0.7834
Fact_A*Fact_B	4	0.2956	0.07389	0.26	0.9008
Error	16	4.5911	0.28694		
Total	26	15.0400			

Grand Mean 7.9333 CV 6.75

Analysis of Variance Table for Days to Fifty Percent Flowering

Source	DF	SS	MS	F	P
Block	2	0.074	0.0370		
Fact_A	2	120.074	60.0370	68.98	0.0000
Fact_B	2	1.185	0.5926	0.68	0.5203
Fact_A*Fact_B	4	1.704	0.4259	0.49	0.7436
Error	16	13.926	0.8704		
Total	26	136.963			

Grand Mean 49.037 CV 1.90

Analysis of Variance Table for Number of Pods per Plant

Source	DF	SS	MS	F	P
Block	2	451.19	225.594		
Fact_A	2	2162.24	1081.12	40.24	0.0000
Fact_B	2	1.08	0.54178	0.02	0.9801
Fact_A*Fact_B	4	0.02	0.00461	0.00	1.0000
Error	16	429.91	26.8696		
Total	26	3044.44			

Grand Mean 87.260 CV 5.94

Analysis of Variance Table for Number of Seeds per Plants

Source	DF	SS	MS	F	P
Block	2	5252.0	2626.0		
Fact_A	2	45666.2	22833.1	135.97	0.0000
Fact_B	2	2.7	1.4	0.01	0.9919
Fact_A*Fact_B	4	5.6	1.4	0.01	0.9998
Error	16	2686.7	167.9		
Total	26	53613.3			

Grand Mean 123.10 CV 10.53

Analysis of Variance Table for Percentage Purity

Source	DF	SS	MS	F	P
Block	2	2.5994	1.29971		
Fact_A	2	1.1730	0.58649	0.73	0.4970
Fact_B	2	1.5534	0.77671	0.97	0.4011
Fact_A*Fact_B	4	1.6653	0.41632	0.52	0.7233
Error	16	12.8427	0.80267		
Total	26	19.8338			

Grand Mean 98.496 CV 0.91

Analysis of Variance Table for Actual Seed Yield

Source	DF	SS	MS	F	P
Block	2	8655	4328		
Fact_A	2	318960	159480	22.57	0.0000
Fact_B	2	2436873	1218437	172.47	0.0000
Fact_A*Fact_B	4	192478	48119	6.81	0.0021
Error	16	113036	7065		
Total	26	3070002			

Grand Mean 691.63 CV 12.15

Analysis of Variance Table for Percentage Shattering Loss of Seeds

Source	DF	SS	MS	F	P
Block	2	4.23	2.11		
Fact_A	2	94.63	47.31	4.63	0.0259
Fact_B	2	4501.79	2250.89	220.31	0.0000
Fact_A*Fact_B	4	76.17	19.04	1.86	0.1661
Error	16	163.47	10.22		
Total	26	4840.29			

Grand Mean 17.074 CV 18.72

Seed Storage Data and Proximate Analysis

Analysis of Variance Table for Germination Percentage

Source	DF	SS	MS	F	P
REP	3	66.9	22.3		
Fact~A	2	3179.1	1589.5	54.66	0.0000
Fact~B	2	5046.9	2523.4	86.77	0.0000
Fact~C	2	26337.4	13168.7	452.83	0.0000
Fact~A*Fact~B	4	1050.1	262.5	9.03	0.0000
Fact~A*Fact~C	4	2185.2	546.3	18.79	0.0000
Fact~B*Fact~C	4	676.2	169.1	5.81	0.0004
Fact~A*Fact~B*Fact~C	8	704.8	88.1	3.03	0.0051
Error	78	2268.3	29.1		
Total	107	41514.9			

Grand Mean 70.472 CV 7.65

Analysis of Variance Table for Seed Conductivity

Source	DF	SS	MS	F	P
REP	3	614.4	204.80		
Fact~A	2	151.3	75.66	5.07	0.0085
Fact~B	2	1318.5	659.25	44.20	0.0000
Fact~C	2	7237.7	3618.87	242.63	0.0000
Fact~A*Fact~B	4	26.0	6.49	0.44	0.7828
Fact~A*Fact~C	4	61.0	15.26	1.02	0.4007
Fact~B*Fact~C	4	21.4	5.34	0.36	0.8376
Fact~A*Fact~B*Fact~C	8	52.0	6.51	0.44	0.8958
Error	78	1163.4	14.92		
Total	107	10645.8			

Grand Mean 36.209 CV 10.67

Analysis of Variance Table for Percentage Moisture Content

Source	DF	SS	MS	F	P
REP	3	0.0818	0.0273		
Fact~A	2	2.3268	1.1634	98.89	0.0000
Fact~B	2	0.1880	0.0940	7.99	0.0007
Fact~C	2	39.6317	19.8158	1684.42	0.0000
Fact~A*Fact~B	4	0.2994	0.0748	6.36	0.0002
Fact~A*Fact~C	4	0.5710	0.1427	12.13	0.0000
Fact~B*Fact~C	4	0.2953	0.0738	6.28	0.0002
Fact~A*Fact~B*Fact~C	8	0.5655	0.0707	6.01	0.0000
Error	78	0.9176	0.0118		
Total	107	44.8771			

Grand Mean 8.3549 CV 1.30

Analysis of Variance Table for Percentage Protein Content

Source	DF	SS	MS	F	P
REP	3	0.3610	0.1203		
Fact~A	2	8.5064	4.2532	131.00	0.0000
Fact~B	2	0.1016	0.0508	1.57	0.2155
Fact~C	2	66.6134	33.3067	1025.83	0.0000
Fact~A*Fact~B	4	0.3537	0.0884	2.72	0.0353
Fact~A*Fact~C	4	7.7803	1.9451	59.91	0.0000
Fact~B*Fact~C	4	0.5878	0.1470	4.53	0.0024
Fact~A*Fact~B*Fact~C	8	0.6025	0.0753	2.32	0.0274
Error	78	2.5325	0.0325		
Total	107	87.4394			

Grand Mean 29.038 CV 0.62

Analysis of Variance Table for Percentage Oil Content

Source	DF	SS	MS	F	P
REP	3	0.01371	0.00457		
Fact~A	2	2.13352	1.06676	193.71	0.0000
Fact~B	2	0.21407	0.10703	19.44	0.0000
Fact~C	2	4.11845	2.05922	373.93	0.0000
Fact~A*Fact~B	4	0.26818	0.06705	12.17	0.0000
Fact~A*Fact~C	4	0.85797	0.21449	38.95	0.0000
Fact~B*Fact~C	4	0.03093	0.00773	1.40	0.2404
Fact~A*Fact~B*Fact~C	8	0.06480	0.00810	1.47	0.1815
Error	78	0.42954	0.00551		
Total	107	8.13117			

Grand Mean 18.337 CV 0.40

Analysis of Variance Table for 1000 Seed Weight

Source	DF	SS	MS	F	P
REP	3	599.31	199.77		
Fact~A	2	2101.06	1050.53	100.51	0.0000
Fact~B	2	2212.62	1106.31	105.84	0.0000
Fact~C	2	1066.82	533.41	51.03	0.0000
Fact~A*Fact~B	4	136.45	34.11	3.26	0.0158
Fact~A*Fact~C	4	30.87	7.72	0.74	0.5687
Fact~B*Fact~C	4	4.73	1.18	0.11	0.9776
Fact~A*Fact~B*Fact~C	8	17.38	2.17	0.21	0.9887
Error	78	815.27	10.45		
Total	107	6984.52			

Grand Mean 120.06 CV 2.69