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FARMERS' PRACTICES IN SOYBEAN (*Glycine max*) STORAGE AND THEIR EFFECTS ON VIABILITY AND VIGOUR OF SEEDS

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UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE FACULTY OF AGRICULTURE

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BY

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DECLARATION

I, Karim Abdul Rahaman declare that this thesis is my original work and has not been presented for the award of degree or certificate of any kind in this or any other University and all materials used for the thesis have been duly acknowledged.

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ABSTRACT

The study was conducted to evaluate farmers' storage methods on the viability and vigour of soybean seeds in Northern Region of Ghana. Soybean seeds were obtained from certified seed producers in the Tamale Metropolis and farmers' seeds from four Districts (Kumbungu, Savelugu, Tolon and Yendi). The work was carried out in three phases; a survey was conducted in June 2016 using Snowball sampling method to identify farmers and ascertain how they store their seeds for planting; field work was also conducted from July to September 2016 to determine the viability and vigour of seeds obtained from farmers and finally a laboratory experiment was also conducted in the regional ultra-modern seed laboratory of the Ministry of Food and Agriculture in Tamale, from October to December 2016 to reaffirm the field experiment. The field experiment was conducted using Nested design. For the field and laboratory experiments, data were collected on the following parameters: germination percentages, plant/shoot height, number of leaves, root length and seedling dry weights. Results from the survey shows that farmers store their soybean seeds mainly in sacks placed on materials (wood and stones). Again, it was also revealed that farmers' in Northern Region stored seeds on their own for planting rather than patronizing certified seeds. Farmers reported diseases and pests as the most important production constraint in the production of soybean in Northern Region. Results from the field and laboratory studies indicate

that certified seeds are significantly ($P < 0.05$) different from farmers seeds in terms of vigour. Seed sources has an effects on viability and vigour

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DEDICATION

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LIST OF ABBREVIATIONS

AOSA	Association of Official Seed Analysis
CSIR	Council for Scientific and Industrial Research
F	Farmer
FAO	Food and Agriculture Organization
GMS	Ghana Metrological Service
HM	Harvest Maturity
IITA	International Institute for Tropical Agriculture
ISTA	International Seed Testing Association
MoFA	Ministry of Food and Agriculture
NASS	National Agricultural Statistics Service
BP	Between Papers
PM	Physiological Maturity
R S I U	Regional Seeds Inspection Unit
SARI	Savanna Agricultural Research Institute
UDS	University for Development Studies
USDA	United State Department of Agriculture
WAS	Weeks after Sowing

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Soybean (*Glycine max* (L.) Merrill) is an important legume which is grown in tropical, subtropical and temperate climates. Like peas, beans, lentils and peanuts, it fit in to the botanical family, Leguminosae, in the subfamily Papilionideae. It has 40 chromosomes (2n = 40) and is a self-fertile species with less than 1 % out-crossing (Shurtleff and Aoyagi 2007; IITA, 2009). Rahman et al. (2011) argues that soybean is considered as an important commercial crop and contained approximately 40 to 45 % protein, 20 to 22 % oil, and 20 to 26 % carbohydrate, greater quantity of Ca, P, and vitamins (Adu - Dapaah et al., 2004; MoFA and CSIR, 2005). The benefits of soybeans are countless; it serves as source of food and feed for human and animals respectively. It is categorised as an oilseed, which contains substantial quantities of amino acids, vitamins as well as minerals for human nutrition. Soya cake serves as an outstanding source of protein for livestock industry in Ghana (MoFA and CSIR, 2005). It serves as a cheap and tremendously beneficiary protein source in the poultry, pig and fish farming industries. Soybean oil has a low content of cholesterol and the world's most extensively used edible oil, its natural sense of taste and nearly imperceptible odour, has branded it the ultimate vegetable oil meant for home and industrial food processing (Mpepereki et al., 2000; Addo- Quaye et al., 1993). Soya oil has also become the most essential raw material for producing biodiesel, which is fast supplementing fossil fuels, a boom in the biofuel industry (Caminiti et al., 2007). The economic and nutritional standard of soybean is being promoted in Ghana by the Ministry of Food and Agriculture, (MoFA) and this resulted to wanton increase in production (Sarkodie-Addo et al., 2006). In West Africa, the crop has come to be an important cradle of high quality and low-cost protein for the deprived and families in the rural areas. It is used in processing cakes, baby foods, soya meat and 'dawadawa', an indigenous seasoning product for soups and sauces, stews, (Abbey et al., 2001). It is also used to supplement several local foods such as soups, 'gari', stew, sauces, 'kenkey' as well as banku to improve their nutritional values (MoFA and CSIR, 2005). Soybean can also contribute to soil fertility improvement by converting atmospheric N into forms that can be utilised by plants. Parts of the fixed nitrogen in the roots in addition to those that remain in the haulms are returned to the soil after harvest thereby improving the soil. This accordingly cuts down the quantity of nitrogen fertilizer farmers would have to apply to their fields to increase yield. This is of greater benefit in African smallholder farming systems, where soils do not contain enough nutrients and inputs are costly and not within the reach of most farmers (MoFA and CSIR, 2005; IITA, 2009). It can as well be useful when it comes to managing *Striga hemonthica,* a widespread parasitic weed of grain crops in the Guinea Savanna zone of Ghana which can cause a significant decrease in crop yield of up to 70-100 % of sorghum, millet and maize. Soybean is not a host plant to striga, but it contains a chemical substance that causes the striga seeds to germinate. Seeds that germinate later die off in a few days since their root system cannot be attached to the soybean plant to take up food substances and water (MoFA and CSIR, 2005). In Ghana, the low levels of production have been linked to small acreages used in cultivation together with indigenous agronomic practices like not applying fertilizers, fungicides, insecticides or herbicides (Asafo-Adjei et al., 2005). Ghana's production of soybean is about 50,000 metric tons per year, out of this, only about 15 metric tons are being used (Dzobefia et al., 2007). In Ghana, soybeans cultivation is done mainly in the Northern, Upper East, Upper West, and Northern part of Volta regions. Amongst these geographical areas, northern Ghana is where the largest production occurs, which is found within the Guinea savanna (Lawson et al., 2008). Northern Region alone contributes about 70 percent of national soybean area and about 77 percent of national production (SRID, 2012). Reasons for the poor harvests of soybean in Ghana include low plant population per hectare for several cultivars of the crop, poor germination caused by quick loss of seed viability, shattering of pod, drought stress and poor nodulation among others (Addo-Quaye et al., 1993).

1.2 Problem statement and justification

The capability of seeds to be stored is mainly regulated by genetic character and this depends on seed quality during storage period, moisture content of seed or ambient relative humidity, pre-storage history of seed (environmental factors during pre and post-harvest stages), duration of storage and biotic agents, temperature of storage environment (Shelar et al., 2008; Baleševiæ-Tubic et al., 2005; Khatun et al., 2009; Biabani et al., 2011). It is inevitable to eliminate seed damage during storage (Balesevic-Tubic et al., 2005). A serious challenge in the soybean seed industry is the production of seeds with low vigour (TeKrony et al., 1980). In many cases, the highest seed quality level achievable is lower than the least acceptable standards. It is not identified yet the effect of environmental influence on seed physiology and biochemistry during development (TeKrony et al., 1980). Environmental stress can decrease the quality of a seed (TeKrony, 1980). Also, the soybean seed quality can be decreased by extreme temperature, rainfall, and fungal infection (TeKrony et al., 1980). Like all legume crops, soybean starts losing quality as soon as they are harvested, processed and/or even during storage. Soybean seed deteriorates much faster compared to various other crops (Priestley et al., 1985). Soybean seed is more susceptible to mechanical injury due to its characteristically weaker structure which makes it deteriorate faster and loss of seed quality (Tekrony et al., 1987; Lori et al., 2001) in post-harvest handling (Shelar, 2008). The seed has a fragile thin coat and can develop cracks if too dry and while being handled, leading to deterioration. These cracks are further multiplied in storage (Ujjinaiah and Sreedhara, 1998; Parde et al., 2002). Bartsch et al. (1979) stated that seed coat and radical or bruising of the cotyledons are more common forms of readily noticeable physical seed damage with cracks below the seed coat that are tough to notice and removed when threshing. Nave (1979) reported that a producer of seeds should be concerned about incurring needless impact damage of seed. Shrivastava and Ojha (1986) reported that soybean is prone to mechanical damage; due to this, germination declines by 10 % when thrown down from an altitude of only 1 meter. High percentage of soybean seed viability and vigour are significant to seed growers, since seed lots that have large quantity of viable and vigourous seeds are required by producers for sowing. Germination is defined as the emergence and development of those essential structures from the seed embryo that are needed to produce a normal plant under favorable conditions (AOSA, 1986). The standard germination test, described in the Rules for

Testing Seeds, the Association of Official Seed Analysts (AOSA, 1986), is the most widely recognized assessment for assessing seed viability globally. Unfortunately, viability tests are insufficient indicators of field emergence for two reasons: 1) field conditions are rarely ideal as expected by normal test conditions, and 2) seedlings are either classified as germinable or non-germinable after a seven-day period without considering the progressive nature of seed deterioration (McDonald, 1980). Seeds can lose viability and vigour before or after physiological maturity (PM), when the seed has its maximum mass and quality, the environmental impact before PM has not been studied much (TeKrony et al., 1980). Extreme temperatures in the development of soybean seed reduce germination percentage and seedling axis dry weight linearly (Keigley and Mullen, 1986). It is reported that the short life span of soybean at storage may be due to certain factors like high oil content and possibly high humidity (Balesevic-Tubic et al., 2007). DeLouche (1980) revealed that severe stress that interrupted the development of seed led to the production of light and wrinkled seeds. TeKrony (1980) found that seed quality was greatly affected by the environment than the genetic effect, resulting in the differences among years. Soybean seed quality can also reduce due to environmental stress between PM and harvest maturity (HM). Low quality seed lots contain a lot of green cotyledons and wrinkled seed coats. After HM, the seed is stored on the plant in the field till harvest. Qualities of seed can deteriorate quickly through this period. Four reasons account for a decrease in the quality of soybean seed after HM: 1) alternate wetting and drying, 2) warm and dehydrated environments, 3) warm and damp environments, and 4) a genetic effect (TeKrony et al., 1980). Seed produced in different environments shows a wide range in terms of viability and vigour. It is relevant, therefore, to look at the ways the environment can decrease seed quality. Throughout post-harvest, soybeans are exposed to losses in quality and quantity because of numerous external factors. The factors can be physical, like temperature and humidity; chemical, like oxygen supply; and biological, like bacteria, fungi, insects and rodents (Brooker et al., 1992). According to Bailey (1974), the qualitative and quantitative characteristics of legumes can be maintained through safe storage, to create unfavorable conditions for insect development, rodents and microorganisms. Storing of grain in the ordinary environment of tropical regions, by Abba and Lovato (1999), has major problems due to temperature and relative humidity as compared to temperate or cold climates. Soybeans contains about 20 % lipids and are thus prone to qualitative deterioration processes through the breakdown of these compounds when improperly stored and can lead to a lot of deterioration in the food industry. With reference to Narayan et al. (1988), chemical, physical and biochemical changes can arise in soybeans; dependent on environmental conditions and time of storage, temperature and relative humidity parameters in storage are decided by the loss process of seed viability and changes in grain color and structure (Whigham and Minor, 1978; Liu, 1997; Lacerda et al., 2003). This has therefore made it necessary for the researcher to investigate farmers' practices in soybean storage (*glycine max* (L) merrill) and their effects on viability and vigour of seeds.

1.3 Research objectives

1.3.1 Main Objective

The main objective of the study was to determine farmers' storage practices and their effects on soybean seed.

1.3.2 Specific Objectives

i. To identify how farmers' store soybean seeds for planting the next season
ii. To determine the effects of farmers' storage practices on the viability of soybeans seeds
iii. To examine the effects of farmers' storage practices on seed vigour of soybean

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution

Soybean is native to Eastern Asia, mostly China, Japan and Korea from where it spread to America and Europe and further parts of the world in the 18th century (Ngeze, 1993). Chinese history has it that soybean has existed over 5,000 year ago, being used as diet and an integral of drugs (Norman et al., 1995). Research has shown that Eastern Africa and Australia are other possible centers of origin of the genus Glycine (Addo-Quaye et al., 1993). Soybean is commonly cultivated in commercial quantities in both the tropical and temperate regions such as China, Thailand, Indonesia, Brazil, the USA and Japan; however, it has turned out to be an important agronomic crop and a main commodity for export (Evans, 1996). It was through Southern Africa that soybean was initially made known to Africa in the early 19th century (Ngeze, 1993) and is presently common throughout the continent. Nonetheless, Shurtleff and Aoyagi (2007) indicated that, the crop ought to be hosted at an earlier date in East Africa, since that region had engaged in transaction long ago with the Chinese. Similar account showed that the crop has remained popular and cultivated in Tanzania in 1907 and Malawi in 1909. In Ghana, soybean was first introduced in 1909 by the Portuguese missionaries. This first introduction failed to flourish because the crop was originated from the temperate (Mercer-Quarshie and Nsowah, 1975). However, soybean production started seriously in Ghana in the early 1970s. This was possible because of the concerted breeding efforts of Ghana’s Ministry of

Food and Agriculture (MOFA) and the International Institute of Tropical Agriculture (IITA) (Tweneboah, 2000).

2.2 World production

The production of soybean is increasing speedily entirely across the world as a result of the consequential benefits. According to the National Agricultural Statistics Service (NASS, 2016), the 2016 soybean planted area is estimated at a record high 83.7 million acres, up 1 percent from last year. In 2009/2010 world soybean production was about 260 million metric tons (USDA, 2011), and for the same period, world average yield per ha was 2371 kg (FAO, 2010). The main producers were the United States (35 %), Brazil (27 %), Argentina (19 %), China (6 %) and India (4 %) with Africa's production being the lowest (9%) with yield of 1.4 tons per hectare. In Africa, the leading producers are Nigeria (592,000 MT) from an area of 625,667 ha, followed by South Africa (332,000 MT) from an area of 199,323 ha, Uganda 176,333 MT from 146,667 ha, with Zimbabwe and Malawi following respectively in fourth and fifth places with productions of 96,008 and 50,000 MT from 60,679 and 71,333 ha, correspondingly (FAO, 2010). The demand for soybeans in the Kenyan market is high, standing at between 50,000 and 100,000 metric tons, against a negligible domestic production of 1,000 to 5,000 MT per year (MOA, 2012). Soybean production level has been very low in Ghana, and its attribution is made to small acreages under production together with unimproved agronomic practices such as non-application of fertilizers, insecticides fungicides or herbicides (Asafo-Adjei et al., 2005). Soybean is among the main industrial and food crops grown in all continents (Dugje et al., 2009).

2.3 Botany

Soybean (*Glycine max* L.) Merrill) plant is a legume and fit into the botanic family leguminosae. Like all other peas, beans, lentils and peanuts, which include some 500 genera and more than 12,000 species, it belongs to the subfamily papilionideae (Shurtleff and Aoyagi 2007). The genus Glycine, presently consist of two subgenera, Glycine consisting of seven perennial wild species confined to Southeastern Asia; and Soja, comprising the domesticated and commercially significant soybean, Glycine max and its wild ancestor, Glycine soja. They are annuals and cultivated in the tropical, subtropical and moderate environments. They have 40 chromosomes (2n=2x=40) and are self-fertile species with less than 1 % out-crossing (Norman et al., 1995). The genus name Glycine eventually was proposed by Linnaeus in his first version of Genera Plantarum; with the cultivated Species first appearing in the edition, 'Species Plantarum', under the name Phaseolus max L. The combination (*Glycine max* L.) Merrill) was projected by Merrill in 1917 and has remained the functional label for this valuable crop (Ngeze, 1993).

2.4 Morphological description

Soybean is a yearly, upright long-haired herbaceous plant, with height between 30 and 183 cm depending on the genotype (Ngeze, 1993). Some genotypic characteristic includes prostrate growing, not greater than 20 cm or grow and develop up to two meters high (Ngeze, 1993). Determinate and indeterminate are the types of growth habits in soybean. Among 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

(Ngeze, 1993; CSIR and MoFA, 2005 and SARI, 2012). Genetically, the determinate type grows shorter and produces fewer leaves, but then produces comparatively more pods, whereas the indeterminate types develop taller, produce more leaves and more pods right from the stem to shoot. Also, the flowers are small, inconspicuous and self-fertile; borne in the axils of the leaves and are white, pink or purple (Ngeze, 1993). The stem leaves and pods remain covered with fine brown or gray hairs. The leaves are trifoliate, having three to four leaflets per leaf. The fruit is a hairy pod that grows in clusters of three to five, each of which is five to eight centimeters long and usually contains two to four seeds (Rienke and Joke, 2005). Soybean seeds occur in various sizes, and in many, the seed coat colour ranges from cream, black, brown, yellow to mottle. The hull of the mature bean is hard, water resistant and protects the cotyledons and hypocotyls from damage (Borget, 1992). Gary and Dale, (1997) have described soybean development in two main stages: the vegetative stage and the reproductive stage. The vegetative stage starts with the emergence of seedlings, unfolding of unifoliate leaves, through to fully develop trifoliate leaves, nodes formation on main stem, nodulation and the formation of branches. While the reproductive stage begins with flower bud formation, through full bloom flowering, pod formation, pod filling to full maturity. Reported Ecoport (2009) Soybean pods usually contain one to three seeds each.

2.5 Soybean importance

Soybean is a legume and normally provides itself nitrogen, through a symbiotic relationship with nitrogen fixing bacteria of the species, *Bradyrhizobium japonicum* (Sarkodie-Addo et al., 2006; Nastasija et al., 2008). Microorganisms found in soybean root nodules will fix nitrogen from the atmosphere, normally supplying most or all nitrogen required by the plant. Soybean grown on soil where well nodulated soybean has been grown in recent years will probably not require inoculation; however, if there is any question about the presence of Rhizobium bacteria, inoculation is recommended (Darryl et al., 2004; Nastasija et al., 2008). The quantity of nitrogen that a plant can fix depends on the variety, the productivity of Rhizobium bacteria, the soil and the climatic conditions. Soybean is capable of fixing between 60 kg and 168 kg of nitrogen per hectare per year under suitable conditions (Rienke and Joke, 2005).

2.5.1 Health

Studies conducted by the American Cancer Society in humans have not revealed harm from eating soya foods. Moderate consumption of soya foods seems harmless for both breast cancer survivors and the overall population and may even lower breast cancer risk." They caution however that soya supplements should be avoided (Dugje et al., 2009). The level of phytic acid in soybean is high, which has several effects including acting as an antioxidant and a chelating agent. The useful assertions of phytic acid include reducing cancer (Vucenik et al., 2003), minimising diabetes (Yoon et al., 1983) and reducing inflammation (Sudheer et al., 2004).

2.5.2 Nutrition

Carbohydrates

Mature soybean contain primary soluble carbohydrates disaccharide sucrose (range 2.5–8.2 %), the trisaccharide raffinose (0.1–1.0%) composed of one sucrose molecule coupled with one molecule of galactose, and the tetrasaccharide stachyose (1.4 to 4.1 %) composed of one sucrose connected to two molecules of galactose.(*intechopen.com.).*

World Health Organization (WHO) calls this the ‘calcium paradox’, where the detrimental effects of animal protein may prevail over the positive effects of the calcium it contains (WHO, 2004). Hence fore it becomes a worthy idea to also focus on consuming protein and calcium rich plant foods. In view of this, it is nutritional advisable to consume soya milk since it is rich in protein and fortified with calcium too. Also, soybean contains isoflavones which aids in bone formation and development as well.

2.6 Conditions necessary for soybean production

2.6.1 Climatic and soil requirements

2.6.1.1.1 Soil

Soybean growth is associated with macroclimate and soil characteristics. However, in much drier Sudan savanna, short-duration varieties can thrive better when sown early and with a uniform distribution of rainfall throughout the growth and development period. Soybean planting is dependent upon temperature and day length. Soybean is a short-day plant and flowering is in response to day’s length. Soybean can be grown on a wide-range of soils with pH ranging from 4.5 to 8.5. To avoid drought stress, soybean should not be planted in sandy, gravelly, or shallow soils. In order to avoid poor emergence, soybean should not be grown in soils with surfaces that can crust, or waterlogged soils (Dugje et al., 2009).

2.6.2 Temperature and photoperiod

Plant breeders argued that within the soybean species, varieties react to photoperiod differently, and are categorized as long day, short day and day neutral plants (Borget, 1992). According to Rienke and Joke (2005), soybean is described as being naturally a short-day plant, physiologically adapted to moderate climatic conditions. However, some have been adapted to the hot, humid, tropical climate. In the tropics, the evolution and development duration of adapted genotypes is commonly 90-110 days, and up to 140 days for the late maturing ones (Osafo, 1997). The relatively short growth duration is generally due to sensitivity to the day length. This subsequently affects the degree of vegetative growth, flowering, and production of viable pollen and length of flowering, pod filling and maturity characteristics (Norman et al., 1995). Most legumes need an optimum temperature of between 17.5°C and 27.5°C for development (Ngeze, 1993). For soybean, the minimum temperature at which it develops is 10°C, the optimum being 22°C and the maximum about 40°C. The seeds germinate well at temperatures between 15°C and 40°C, but the optimum is about 30°C (Rienke and Joke, 2005). Addo-Quaye et al. (1993) have suggested the optimum temperature for growth as between 23-25°C.

2.6.3 Moisture requirements

Optimum moisture is required for soybean seeds to germinate and develop well. The optimum rainfall amount is between 350 and 750 mm, well distributed throughout the growth cycle (Ngeze, 1993). Rienke and Joke, (2005) and Addo-Quaye et al. (1993) report that two periods are being critical for soybean moisture requirement; from sowing to germination and flowering, and pod filling periods. And during germination, the soil needs to be saturated with water between 50 % and 85 %, as the seed absorbs 50 % of its weight in water before it can germinate. Water requirement increases, and peaks up at the vegetative stage, and then decreases to reproductive stage, and then decreases to reproductive maturity. Largely, difference in the quantity in addition to distribution of soil water confines soybean yield. According to Bohnert et al. (1995), water play two significant roles in plants, as a medium for dissolution and transportation of plant nutrients, and as an electron giver in the photosynthetic reaction processes.

2.6.4 Plant spacing and sowing

Soybean is planted by hand, planter, or by drilling, 3 to 4 seeds can be planted per hole. Spacing should be 75 cm between rows and 10 cm between stands. Otherwise, seeds can be drilled at 50–75 cm between rows and 5 cm within rows. A spacing of 50 cm between rows and 5–10 cm within rows is commended in planting early maturing verities since they respond better to narrow spacing than the late-maturing varieties. Seeds should not be sown deeper than 2–5 cm. Seeds planted deeper than recommended depth may result in loss of potency or failure of seedlings to emerge (Dugje et al., 2009).

2.6.5 Harvesting soybeans

Maturity of soybean mostly depends on the variety and requires well-timed harvesting to reduce extreme yield losses (SARI, 2012). Soybean when left on the fields after pods are dry, the seeds start to deteriorate, particularly while it is still raining (SARI, 2012). At maturity, the pods are straw- colored at maturity. Harvesting of the non-shattering variety is recommended when roughly 85 % of the pods have turned brown however 80 % for shattering varieties. Alternatively, harvesting of soybean can be done with a hoe, a cutlass, or sickles. Cutting of the plant can be done when the seeds are at the hard-dough stage, with moisture content between 14 and 16 %. Varieties that are new resist shattering but losses in yield could occur from other causes if harvesting is done on time. Cutting of mature plants should be done at ground level. Stack harvested crops loosely on tarpaulin/material and allow them to dry in the open for 2 weeks before threshing. Farmers should not harvest soybean by hand pulling since this might take away the nutrient that the soybean has added to the soil (Dugje et al., 2009). According to Dugje et al. (2009), the Jenguma (TGX 1448-2E) variety of soybean is recommended for the Southern and northern Guinea savannas agro-ecological zones of West Africa for cultivation following its characteristic in medium maturing, high yield, low shattering, high oil content, excellent grain color. Selection of soybean variety should be based on maturity, yield potential, lodging, drought tolerance, and resistance to pests and diseases. Maturity period should be the primary factor to consider when deciding on soybean variety suited to your ecological zone. It is preferred to consider early maturing varieties than late maturing verities in area with low rainfall. It is too risky to cultivate late-maturing varieties in drier locations because of late-season drought even though later maturity increases yield potential, (Dugje et al., 2009). If soybeans on the field after the pods are dry, the seeds may shatter, especially in the Guinea Savanna zone where the dry harmattan winds can speed up the shattering process (Asafo-Adjei et al., 2005). 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 uprooted and heaped at various points (Asafo-Adjei et al., 2005). Harvesting of matured soybean seeds on time is certainly important in maintaining high seed quality. Harvest delays beyond optimum maturity increase field exposure and intensify seed deterioration. Seeds vigour declines after 30 days of harvest maturity, particularly in warm, tropical prevailing conditions (Tekrony et al., 1984).

2.6.6 **Soybean storage**

Delouche (1968), defined the total seed storage period as comprising segments of bulk storage, which is the period from harvest through packaging including conditioning. The purpose of storage is to preserve harvest quality of product, not certainly to increase 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 quantity of moisture in the seeds, coupled with the temperature within the store is most likely the essential factors influencing seed viability during storage (Gokhale, 2009). In storage, soybean seed rapidly loses its viability (Pratt et al., 2009). Shelar et al. (2008) pointed out that the germination effectiveness (viability) of other oilseed plants have better stand as compared to soybean which has very short lived and usually decline prior to time of planting. These losses in germination remained considerable more severe in temperate conditions. These macro and micro conditions make very demanding to preserve viability of seeds for the period of storage (Shelar et al., 2008). Khaliliaqdam et al. (2012) also stated that soybean seeds germination potential declines more rapidly during storage than it does in other grain crops. Soybean quality during storage the pursuit of quality grain and sub-products should be a priority for producers, processors and for distributors of these products. According to (Brooker et al., 1992), the key features which are used as determinants of quality in soybean are: low and uneven moisture content; low percentage of foreign material, discoloration, susceptibility to breakage, injury of the heat (internal cracks) fungal damage, and insect, high values of density, concentration in oils and protein and seed viability. Prevailing environmental conditions for the period of grain development on plants, time and harvesting system, drying system, practices in storage, transportation and physical characteristics of the species, and the variety are factors that can affect seed quality. Qualitative and quantitative losses occurred in stored grains because of the following key biological factors; insects, mites, rodents and fungi are the main biological factors responsible for, where development of these organisms is accelerated by ecological factors such as relative humidity and temperature (Padin et al., 2002). Seed quality has many criteria that involve several significant seed qualities: genetic and chemical composition, physical condition, physiological germination and vigour, size, appearance and existence of seed borne diseases, crop and varietal purity, weed and crop impurities and moistness. At storage, the initial seeds quality level can remain or decrease to a level that make the seed undesirable for planting. What is related to many determinants: environment's conditions during seed production, pests, diseases, seed oil content, seed moisture content, mechanical damages of seed in processing, storage longevity, package, pesticides, air temperature and relative air humidity in storage, biochemical injury of seed tissue and similar (TeKrony et al., 1987; Reuzeau and Cavalie, 1995; Anfinrud, 1997; Al-Yahya, 2001; Šimic et al., 2004; Guberac et al., 2003; Heatherly and Elmore, 2004). The rate at which seed quality decline at storage differ among plant species and within plant species (genotypic variability), involving significant influence of genetic (heritable) constituent on phenotypic manifestation of traits which determine seed quality. Soybean seed is well-known for its short storage life and is presently not carried-over to the succeeding planting season under tropical conditions, it has been established that soybean seed viability and vigour rapidly reduced during storage at ambient temperatures (Nkang and Umoh, 1996). Deterioration of seed during storage is unavoidable and decline in value is influenced by temperature and relative air humidity in storage, moisture content of seed, length of storage, variety of seed, and seed initial quality (Adebisi et al., 2004; Fabrizius et al., 1999). Seed quality is a multiple criterion that encompasses several important seed attributes: genetic and chemical composition, physical and physiological condition, germination and vigour, size, appearance and presence of seed borne pathogens, crop and varietal purity, weed and crop contaminants and moisture contents. During storage, seed quality can remain at its initial level or decline to a level that may make the seed unacceptable for planting purpose. This is connected to many factors: ecological conditions during seed production, pests, diseases, seed oil content, seed moisture content, mechanical damages of seed during processing, storage longevity, packaging, pesticides, air temperature and relative air humidity in storage, biochemical injury of seed tissue, etc. (Simic et al., 2004, 2007). Seed longevity in storage is influenced by the initial quality of stored seed as well as conditions of storage. Irrespective of seed initial quality, unfavorable storage conditions, particularly air temperature and air relative humidity, contribute to acceleration of seed deterioration in storage. Hence, it is challenging to evaluate effective storage period because seed storability is a function of initial seed quality and conditions of storage (Heatherly and Elmore, 2004). Irrespective of genotypes, germination potency of soybean seeds decreased during storage (Shelar, 2002). Seed genetics, seeds production environment and storage environment are the three major factors that influence seed viability and vigour (Sun et al., 2007). Deterioration in viability is intricately linked to seed moisture content, which is in turn controlled by the relative humidity of the storage environment (Barton, 1943; Vieira et al., 2001). Seed viability as well as seed vigour can greatly be influenced by the environment where seed develops (Sun et al., 2007). The seed production environments are defined by the availability of soil nutrients, soil moisture, and the temperature and relative humidity during seed development and maturation (Sun et al., 2007). Dugje et al. (2009) reported that soybean seed is sufficiently dry when it cannot be dented with the teeth or fingernails. At harvest, the grains usually contain about 14 % moisture. They recommend that soybean seeds should be dried to 13 % moisture for storage of 6–12 months and to 10–11 % for longer storage. Soybean can best be protected in storage by practicing open-air drying. Place 50-kg or 100-kg bags of clean soybean on a rack in the cold room or in shade. High moisture content in stored soybean encourages the development of various agents of deterioration, such as insects and microorganisms (Dugje et al. 2009). Good storage management can greatly influence the storability of soybean and succeeding germination when planted in the field. Soybean should not be exposed to high temperatures, as it will increase deterioration and reduce seed viability. Dugje et al. (2009), said that soybean seeds easily lose their viability; it is common for soybean, even when stored properly, not to germinate after 12 –15 months in storage. Therefore, seeds that are not more than 12 months old should be used for planting to ensure good germination.

Soybean with high moisture content during storage encourages the development of several agents of deterioration, such as insects and microorganisms. Seeds should not be bought from the open market because the germination potential is not assured. Gokhale (2009), stated that seed longevity in storage can be affected by the following; 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), rodents and birds infestation, seed treatment and fumigation, and period of storage in transit. The author again indicated that the volume of moisture in the seeds, coupled with the temperature within the store is perhaps the fundamental 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 amount of the percent relative humidity plus the temperature in degrees Fahrenheit should not go beyond 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 moisture content of seed is traditionally used to provide the data upon which storage decision is based (Hampton, 1990).

2.6.7 Challenges in soybean cultivation

During the vegetative growth stage, soybean can tolerate caterpillars but so prone to silver leaf whitefly attack. After flowering, soybean attracts pod-sacking bugs that can extremely cause a reduction in seed quality. Soybean diseases generally cause yield loss in Nigeria. Fungi, virus and bacteria are some common diseases of soybeans. One of the main limitations of soybean farming is the availability of less vigorous seeds at planting time (Gupta and Aneja 2004). Soybean is comparatively a new crop in Ghana and hence has few documented insect pest issues. In various locations, damage caused by insect pest to soybean can be insignificant. In other locations however, leaf eating caterpillars and pod-sacking bugs can lead to serious losses in yield if not controlled. The pod-sacking bugs suck sap from pods and seeds that are developing making them to shrink and drop-off (Asafo-Adjei et al., 2005). Reported by Dugje et al. (2009), further noted that, many kinds of insects occur in soybean farms however a small number are usually of economic benefits.

2.6.8 Soybean seed viability

Seed viability signifies the degree to which a seed is alive, metabolically active and possesses enzymes necessary for catalyzing metabolic reaction needed for germination and seedling growth after storage (Basra et al., 2002). Loss of viability of stored seeds often hampers soybean (*Glycine max* (*L.*) Merril). Exposure to warm, moist air typical of the humid tropical regions is principally responsible for this. Seed deterioration in storage, can best be arrested by using commended dry-cold conditioned storage structures even though they are costly (Ng, 1988). FAO (2010), stated that seed can only fulfil its biological role when viable. Consequently, seeds with physical and uniform variety will not be useful if it has low germination or if it cannot germinate when sown. Seed viability is affected by several conditions. Some plants produce seeds without functional complete embryos or seeds with no embryo at all, usually called empty seeds (FAO, 2010). Soybean grows in diverse agro-ecological conditions; therefore, seed germination and vigour are affected by numerous unfavorable environmental influences such as drought, extreme temperatures, untimely sowing, etc. (Casenave and Toselli 2007). 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 favorable conditions in soil. In early harvested seed crop, the quality of seed will be much low due to more number of immature and undeveloped seeds, whereas in delayed harvesting, seed quality is affected on account of field weathering (Vasudevan et al., 2008).

2.7 Soybean seed vigour

A vigorous seed lot is one which is able to do well even when environmental conditions are not optimal for the species (ISTA, 2011). Seed vigour therefore is a measure of the level of destruction that accumulates as seed viability declines until seed is incapable of germinating and finally dies. Therefore, a vigorous seed lot ought to perform well even if environmental conditions are not the best for growth of that specific species. The concept of seed vigour was developed to complement viability. 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). The Association of Official Seed Analysts defined vigour in the Vigour Testing Handbook (AOSA, 1983) as those seed properties that determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions. Accepted vigour tests include: 1) the accelerated aging test to evaluate seed storability, 2) the cold test to evaluate emergence ability in cool, wet, unsterilized soils, 3) the conductivity test to estimate seed membrane integrity, 4) the cool germination test to estimate germination ability in a cool microorganism-free environment, 5) the relative growth rate test to evaluate the capability of converting seed storage reserves into seedling axis dry weight, 6) the seedling vigour classification test to allow partitioning of germinated seedlings into strong and weak categories, 7) and the tetrazolium test to identify living seed tissues. TeKrony and Egli (1977) found that the range in vigour test values was wider than for the standard germination test values indicating an improved ability to distinguish quality differences among seed lots. Seed vigour results were more identical to field emergence under stress conditions than standard germination test results (Egli and TeKrony, 1979). Germination test of seeds should be carried out prior to planting; the rate of germination should be above 85 % to obtain a good stand (Dugje et al., 2009).

2.8 Sources of variation in soybeans seeds vigour and viability

Differences in micro-environment could be the possible cause of variation in seed viability which consequently subject seeds to predisposed loss or decline. Differences in canopy position have been reported to cause variation in seed viability (Smiciklas et al., 1992; Adam et al., 1989). Quality attributes variation of seeds in a seed lot can result from variation between plant features of the crop where the seed lot is produced from, differences in natural conditions in a crop and differences occurring from cultural practices. Favorable temperatures and marginal rainfall for the period of seed development contribute to greater viability and vigour seeds (Copeland and McDonald, 2001). Considerably less significant germination rates occur at late stages of seed development with higher temperature than initial stages of seeds (Egli et al., 2005; Spears et al., 1997). Sufficient nutrients in the soil generally enable seeds to possess enough storage materials use for the period of germination as well as seed and seedling up until seedling photosynthetic ability is established (Justice and Bass, 1978). Additionally, seed growth and development could be affected by environmental factors such as light, water and the type and amount of nutrients available (Pallais et al., 1987). Seed quality and yield is said to be affected by insufficient water during seed filling as well as pathological damage (Dornbos et al., 1989). Light weight and poor shriveled seeds are caused by moisture stress, deficiency in nutrients and extreme temperatures during seeds development. Hampton, (1995) reported that, it is often significant for differences to occur in seed viability and vigour between and within seed lots, since many factors affects seeds quality attributes. The basis for these differences is the consequences of decisions made during planning of seed production, plant physical characteristics and management or conditions of the environment for the period of growth and development, harvesting, processing and seeds storage (Carter and Hartwig, 1963). The numbers of emerged seedlings, the mean period between planting and seedling sprouting and the length of time to emerge for different seedlings in a crop are factors influenced by seed quality (e.g. Finch-Savage, 1995). Effects of seed quality on the level of seedling growth after emergence as well has been reported (Perry, 1984a; Ellis, 1992; Burris et al., 1973). Seed quality is a complex trait that is determined by the genetics, physical, physiological and health properties of a seed (Delouche and Baskin, 1973; McDonald, 1999; Marco-Filho et al., 1998). These properties are in turn influenced by the agro ecological conditions in the seed production field, seed handling and processing, storage conditions and storage period (Vieira et al., 2001; McDonald, 1998). At each stage of the seed production process, great care is taken by the seed producer to ensure optimum quality. Seed vigour can be measured through germination rate, seedling length, root length, seedling fresh weight, seedling dry weight, seed longevity, and tolerance to adversity. These vigour-related traits are quantitative in nature and often interact with the environment during seed maturation, harvest and storage to determine the vigour of the seed at any point in time (Sun et al., 2007). However, to produce seed of high quality, many complex technologies are required during the seed production phase. During planting, growth and development, harvesting, processing and storage, careful handling will protect the seed from mechanical injuries, adverse environmental conditions, pests, and diseases (McGee, 1995). According to Copeland and McDonald (2001), marginal rains and good temperatures in seed development can lead to the production of viable and vigorous seeds. Seeds management practices, environmental conditions during sowing, soil and seeds quality according to (Coolbear, 1995; Dornbos Jr., 1995) are the possible factors responsible for seed lots differences. These again may be partially initiated by the factors above (variations in light, variation in soil conditions in location and quality of seed) in a crop. Viability and vigour qualities of seed is characterized by genetics, physical, physiological as well as health properties of a seeds (Delouche and Baskin, 1973; McDonald, 1999; Marco-Filho et al., 1998). Seed properties are influenced by field environmental conditions during seeds production, seeds management practices, conditions during storage as well as duration (Vieira et al., 2001; McDonald, 1998). Joshiet et al. (2009) found a significant and positive correlation of plant height with seed vigour. The main constituents of soybean seed vigour are seedling length and dry weight. . The main constituents of soybean seed vigour are seedling length and dry weight. These two traits along with germination percentage have significant and positive association with seed vigour (Egli et al., 1990; Egli and Tekrony, 1996; Joshi et al., 2009, Singh and Chauhan, 2010 and Rezapour et al., 2013). Standard germination test shows non-significant correlation with field emergence under unfavorable environmental conditions (Johnson and Wax, 1978; Vieira et al., 1991). Therefore, vigour tests are considered more adequate than standard germination tests for estimating field performance (Byrd and Delouche, 1971 and Abdul- Baki and Anderson, 1973). Laboratory indices of germination percent and seed vigour index have high correlation with field emergence

(Jafari et al., 2013 and Sheidaei et al., 2014). Field emergence and laboratory germination tests have low broad sense heritability estimates due to large environmental variances (Green and Pinnell, 1968). Germination test is an analytical procedure to evaluate seed quality under favorable conditions. Germination percentage had significant positive correlation with field emergence (Yaklich and Kulik, 1979; Egli and Tekrony, 1995; Tekrony and Egli, 1997; Saha and Sultana, 2008; Khaliliaqdamet al., 2013; Naderidarbaghshahi and Jalalizand, 2013; Prochazka et al., 2013). Seed that germinates in a shorter period have a higher vigour index due to direct relationship between speed of germination and seed vigour (Nakagawa 1999). The ideal depth of sowing for best emergence is 2.5 to 3.8 cm and never deeper than 5 cm (Herbek and Bitzer, 1988). Three cm depth of sowing had similar performance for all the grades (Khare et al., 1995). However, Aikins et al. (2011) concluded 5 cm as appropriate depth for sowing. Dry matter per seedling is not an appropriate method for evaluation of seed quality (Santos et al., 1987) as it may be influenced by seed vigour (Gilman et al., 1973 and Nobrega and Vieira, 1995; Burriset al., 1973).

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study consisted of field survey and field and laboratory experiments.

3.1 Survey to identify how farmers store soybean seeds

A survey was conducted in four districts in the Northern Region of Ghana (Yendi, Tolon, Kumbungu and Savelugu) to identify how local farmers store soybean seeds for planting the next season. The selection was based on the scale of production of soybean in the region. In each district, four communities were randomly selected.

3.1.1 Sampling methods and sampling size for survey

Purposive sampling was used to select the four districts for the study; simple random sampling method was also used to choose four (4) communities each in the four districts making sixteen communities. Finally snowball sampling method was used to identify hundred and sixty (160) soybean farmers in the various communities under the four districts.

3.1.2 Data collection procedures

Qualitative and Quantitative data were collected using close and open ended structured questionnaires (appendix 1) for the survey work to identify how local farmers' store soybean seeds for planting the next season.

3.2 Field experiment to determine the effects of farmers' practices on viability and vigour of soybean seeds

The field experiment was conducted at the research farm of the University for Development Studies at Nyankpala campus which lies on latitude 9°25 N and longitude 9°58 W with altitude 185m above mean sea level (SARI, 1997). The annual rainfall is 1034 mm with monthly mean temperature of 22°C in the rainy season and 34°C in the dry season (SARI, 2004). The field work was conducted to determine the effects of farmers' storage practices on the viability and vigour of soybeans seeds.

3.2.1 Experimental design and field layout

Nested design was used to lay the experimental field. Farmers were nested in communities and communities were also nested in Districts.

3.2.2 Seeds source and sampling method for field experiment

A total of 160 kg lots of sample seeds were purchased from 160 farmers (1 kg of seeds from each of the 160 farmers). Out of the purchased seed lots, fifty-four (54) farmers' soybean seeds of variety "Jenguma" were randomly selected. In the four districts where the survey was conducted, three communities were randomly selected, and for each community, four farmers were also randomly selected given a total of twelve (12) farmers in each district from whom seeds of soybean variety "Jenguma" were obtained. This gave a total of 48 seed lots. Three seed growers from the Tamale Metropolis were also selected from whom four seed lots each from their seeds (Jenguma) were also sampled and added to the 48 seed lots from the farmers making a total of 60 seed lots which were used for both the field and the laboratory for experiments.

3.2.3 Land preparation

The field was ploughed on June 25th, 2016 using a tractor. It was then harrowed using tractor drawn harrow and demarcated into plots each measuring 0.1 acres. The size of the experimental field was 0.5 acres in five plots.

On July 7th, 2016 the seeds were sown. One seed was sown per hole at a spacing of 60 cm between rows and 5 cm between stands. Hundred seeds were planted per row for each treatment and replicated four times.

3.3 Data collection procedures in the field

In the field, data were collected on germination count, plant height, number of leaves, seedling, shoot and root lengths, and dry weight shoot and root per plant.

3.3.1 Germination count in the field

Germination data was collected daily on the field by counting the number of seedlings which emerged daily. This lasted for two weeks (14 days) starting from the 4th day after planting. Germination percentage was calculated as follows:

Germination percentage = (Normal seedlings emerged / total seeds sown) ×100

Plate 1: Field germination in second week

Plate 2: Field germination in the fourth week

3.3.2 Plant height

Plant height was measured from the ground level to the highest tip of the stem for ten sampled plants from each plot. This was done weekly for a period of four weeks with the aid of a meter rule. Average plant heights were subsequently calculated.

3.3.3 Number of leaves

The numbers of leaves of the ten-sampled plants were also counted weekly for a period of four weeks. This was done manually, and the average sampled plants were also computed at each period.

3.3.4 Uprooting of plants

Sixty-one days (61) days after planting, the ten sampled plants were removed from the field for each treatment and data on root and shoot length and root and shoot dry matter were collected.

Plate 3: Uprooting of sampled plants in nine weeks after planting

3.3.5 Seedling root and shoot lengths

Seedling root and shoot lengths of the ten sampled plants were taken with the use of a meter rule to determine vigour. Vigour index was determined according (Abdul-Baki and Anderson, 1973) as fallows;

Vigour Index = (Shoot length + Root length) × Germination %

3.3.6 **Dry weight**

At 61 days after planting, fresh shoot weights were taken respectively from the ten sampled plants with a digital scale and subsequently oven dried in the laboratory at the University for Development Studies in the Nyankpala campus at a temperature of 100°C for a period of twenty four (24) hours and the dried weight were then taken.

3.4 **Experiment 3: Germination test in the laboratory**

The laboratory work was conducted at the Regional Ultra-Modern Seed Laboratory of the Ministry of Food and Agriculture in Tamale, Ghana. Germination test was conducted by using Between Paper (BP) Method in accordance with Intentional Rules for Seed Testing (1985). Hundred (100) seeds were randomly taken from each of the sixty (60) farmers' seeds initially sampled for the field test and replicated four times. The laboratory work was conducted to complement the field work and reaffirm the objectives below;

- To determine the effects of farmers' storage practices on the viability of soybeans seeds
- Examine the effects of farmers' storage practices on seed vigour of soybean

3.4.1 **Procedure used for germination test in the laboratory**

Seeds were plated in hundreds and kept in between two layers of papers towel placed on plastic bag in four replicates. The seeds were covered with an additional layer of paper. Towel papers were rolled and placed in an upright position. Finally, the substrates were placed in trays in a germinator which was set between 25°C to 30°C throughout the germination period while 12 hours light and darkness were both provided daily.

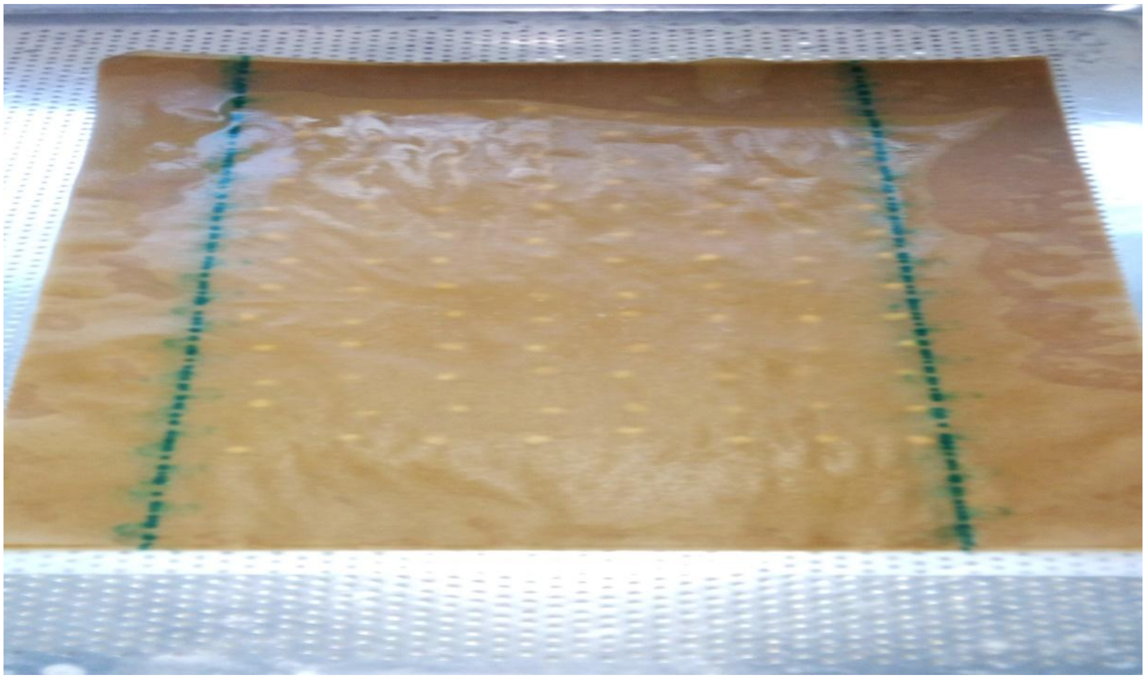

Plate 4: Plated seeds for laboratory germination test

Plate 5: Sorting of soybean seeds for plating

Plate 6: Soybean seeds set for germination in the germinator

3.4.2 Data collection procedures in the laboratory

Data was collected on the following parameters: germination count, root and shoot lengths.

3.4.3 Germination count

In the laboratory, germination count was done daily on the germinated seeds from the 4th to 10th days as prescribed in the Association of Official Seed Analysts Vigour Testing Handbook (AOSA, 1983). Seeds with emerged radicle were considered germinated.

Plate 7: Germinated seeds at one week after laboratory test

3.4.4 Shoot and root lengths

Shoot length was measured on the 10^{th} day from the hypocotyl to the highest tip of the shoot for ten sampled plants from each treatment whilst root length was also measured on the same day from the hypocotyl to the tip of the root. The vigour index was determined as in section 3.3.5.

3.4.5 Data analysis and presentation

The survey data was analyzed using Statistical Package for Social Sciences (SPSS) version 17. The field and the laboratory experimental data were also analyzed in one-way ANOVA using GenStat Statistical Package (Edition 4) and the treatment means were compared using the Least Significant Difference (LSD) at 5 % level of probability. Results are presented in tables, charts and figures.

CHAPTER FOUR

4.0 RESULTS

4.1 Experiment 1: survey to identify how farmers' store soybean seeds

The age ranges of the respondents are presented in Figure 1. According to Figure 1, majority (48.1 %) of the soybeans farmers were within the age range of 35-60 years. However, a sizeable number of the farmers (40.6 %) also fell within the youth bracket (18-35 years) which is encouraging. Only few (11 %) of aged farmers were involved in soybean production.

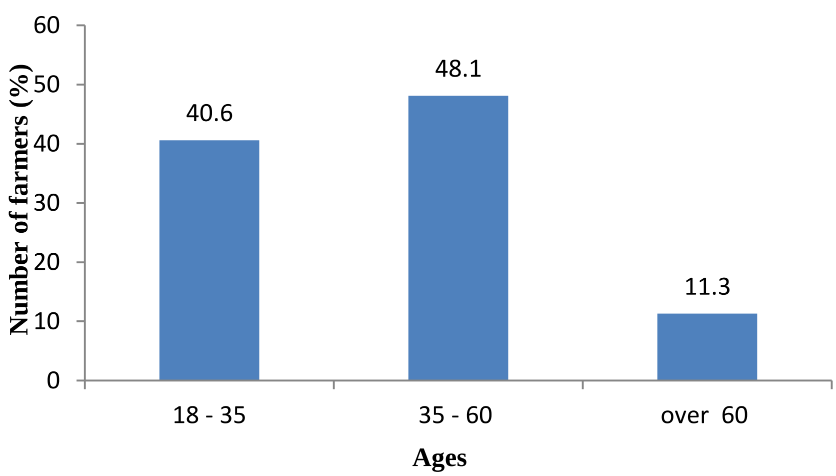

Figure 1: Age of respondents

Responses from the survey work indicated that most (73.8 %) of the soybean farmers in the Northern Region of Ghana are illiterates (Table 1). Only 10 % of the farmers had senior high school or higher education.

Table 1: Educational level of respondent in years

Level of Education	N = 160	Percent (%)
No Education		73.8
Primary		6.9
Junior High		8.1
Senior High		9.4
Non-Formal		0.6
Tertiary		0.6
Total		**100**

Table 2 indicates that majority of the farmers in Northern Region have smaller landholdings available for farming; 112 respondents representing 70 % possess a land area of less than 5 hectares for farming; 20 % also possess a land area of 5-9 hectares for farming while only 4 % have land more than 14 ha.

Table 2: Arable land available for farming

Land Size (Hectares)	N= 160	Percent (%)
Less than 5		70
5-9		20.6
10-14		5.0
15-19		4.4
Total		**100**

Table 3 Shows that soybean is cultivated on small scale in the Northern Region of Ghana. Majority (83.6 %) of the farmers allocate less than 2 ha of their farm land for soybean cultivation while few (2.55 %) farmers allocated more than 7 ha for soybean cultivation in 2015.

Table 3: Size of soybean field cultivated in the year 2015

Size of soybean field last year (Hectares)	N = 160	Percent (%)
0-3		83.6
4-7		14.5
8-11		2.5
Total		**100**

Table 4 shows that sixty-nine (69) respondents representing 43 % of the soybean farmers had been cultivating soybeans for less than 5 years. Thirty two percent of the farmers have been cultivating soybean for 5-10 years.

Table 4: Experience in the cultivation of soybean

Number of years	N = 160	Percent (%)
Less than 5		43.1
5-10		32.5
10		24.4
Total		**100**

Table 5, ninety-three (93) soybeans farmers representing 58.1 % select soybean variety based on its non-shattering ability and 46 (28.8 %) farmers selected soybean variety based on yield.

Table 5: Criteria for selecting soybean for planting by farmers

Variety	N = 160	Percent (%)
Does not shatter		58.1
Early maturing		12.5
High yielding		28.8
Late maturing		0.6
Total		**100**

Evidence from the survey revealed that soybean farmers in the Northern Region have been cultivating soybean variety "Jenguma" only within the last 6 years. From the survey 80 respondents representing 50.1 % went into the production of 'Jenguma' within the last 3-6, 49 respondents representing 29.9 % went into' Jenguma' production in the last two years and 31 respondents representing 20 went into 'Jenguma' production 7 years ago (Table 6).

Table 6: Number of years of cultivating the soybean variety Jenguma in Northern Region

Number of Years	N = 160	Percent (%)
1-2		29.9
3-6		50.1
> 6		20
Total		**100**

The proportions of estimated income earned by soybean farmers in Northern Region are shown in Table 7. About 54 % of the farmers earn their household income from the production of other crops other than soybean while 31.2 % of the farmers derived their income by the cultivation of soybean alone; 7.6 % farmers earn their household income from the rearing of animals.

Table 7 : Sources of income for soybean farmers in Northern Region

Production	N=160	Percentage (%)
Crops other than soybean		53.7
Soybean		31.2
Livestock		7.6
Casual labour in agriculture		0.6
Casual labour off-farm		0.1
Trade		1.4
Other business		1.9
Salaried job		0.7
Remittances		0.3
Other		2.5
TOTAL		**100**

Table 8 shows that majority (83 %) of the farmers use small part of their harvested grains of soybeans for home consumption and most part for sale. Although soybean has high nutritional value in terms of protein, very little is consumed by farmers who produce the crop partly due to lack of knowledge in the processing of the crop.

Table 8: Proportion of total soybean used for home consumption and for sale

Household Uses of soybean	N = 160	Percent (%)
All produce used for home consumption		1.9
Most produce used for home consumption, small part used for sale		11.9
Half of the produce used for home consumption, half of produce used for sale		1.9
Small part used for home consumption, most part used for sale		83.1
No produce use for home consumption, all produce used for sale		1.3
Total		**100**

Pest and diseases incidence is the most important challenge faced by soybean farmers in the Northern Region of Ghana (Table 9). Other major challenges are access to input (14.4 %) and output (26 %) market. Perceptions of farmers were that disease and insect pests are the major challenge in soybean cultivation is surprising.

Table 9: Challenges in soybean cultivation

Responses	N = 250	Percent (%)
Viability of seed	9	3.6
Marketing of grains	65	26
Pest and diseases	132	52.8
Poor access to input services	6	14.4

(including tractor services)		
Inadequate finance	8	3.2
Total	**250**	**100**

From Figure 2 below, out of the one hundred and sixty (160) farmers who were interviewed, 99 % of the farmers store their own soybean seeds for planting in the next season and only 1 % of the farmers rely on seeds from their neighbours.

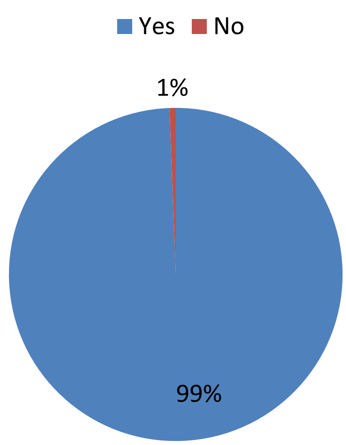

Figure 2 : Source of seeds for planting by farmers

61.3 % of soybeans farmers' store their seeds in sacks (Nylon) placed on top of wooden materials and 22.5 % store their seeds in sacks and placed on the bare floor. However, 0.6 % of the farmers store their seeds in sacks placed on rack and also in local pot (Table 10).

Table 10: Farmers' methods of storing soybean seeds

Storage method	N = 160	Percent (%)
Kept in polybag, put in sacks and placed on top of wood		3.1
Kept in polybags, put in sacks and placed on bare floor		1.9
Put in sacks and placed on bare floor		22.5
Put in sacks and placed on racks		0.6
Put in sacks and placed on top of stones		9.4
Put in sacks and placed on top of wood		61.3
Store seeds in local pot		0.6
Total		**100**

Table 11 below show the storage methods of farmers whose seeds were sampled from the various districts and certified seeds for both the field and laboratory experiment. In Kumbungu District, out of 12 sampled farmers, 2 farmers stored their seeds in polybag, put in sacks and placed on top of wood while 9 farmers stored their seeds in sacks placed on top of wood. However, 1 farmers stored seeds in sacks and placed on top of stones. In Savelugu Municipality, all the 12 farmers stored their seeds in sacks and placed on top of wood. Similarly, in Tolon district out of 12 sampled farmers, 10 stored seeds in sacks placed on top of wood while 1 farmer each stored in sacks placed on bare floor or kept in polybag, put in sacks placed on top of wood. Also in Yendi Municipality, out of 12 farmers, 10 stored in sacks placed on top of wood whereas 1 farmer each stored in sacks placed on top of stones or stored in sacks and placed on bare floor. In the case of Certified seeds, all the 12 farmers stored seeds in sacks placed on top of wood.

Table 11: Storage methods for sampled farmers used for the field and laboratory experiments

District	Storage methods				
	Kept in polybag, put in sacks and placed on top of wood	Put in sacks and placed on bare floor	Put in sacks and placed on top of stones	Put in sacks and placed on top of wood	Total number of farmers sampled
Kumbungu	2	0	1	9	12
Savelugu	0	0	0	12	12
Tolon	1	1	0	10	12
Yendi	0	0	2	10	12
Certified Seeds	0	0	0	12	12

Table 12 shows that 41.3 % of the farmers carry out germination test on their stored soybeans seeds before planting and 58 % did not carried out germination test.

Table 12: Test for seeds for germination, viability or vigour potential

Responses	Frequency	Percent
Yes	66	41.3
No	94	58.7
Total	**160**	**100**

Table 13 shows that 58 % of farmers did not conduct germination test on their stored soybean seeds before planting in the field whereas 38 % said they conduct germination test by sowing sample of their stored seeds to determine the germination percent before using the seeds.

Table 13: Farmers method of testing for germination

Test method	N = 160	Percent
No test		58.8
Cocoa sack method		0.6
Physical examination		0.6
Soil testing		38.8
Water testing		1.3
Total		**100**

About 46 % of the soybean farmers recorded 90 % and above germination rate of their stored seeds used for sowing in the 2015 cropping season during their seed testing before sowing in the field (Table 14).

Table 14: Germination percentage (%) recorded in the year 2015 by farmers

Germination percentage % recorded in previous year	N = 66	Percent
Less than 40 %		4.5
40 – 60 %		4.5
60 – 80 %		45.5
90 % and above		45.5
Total		**100**

According to Table 15, 40.9 % of farmers considered 90 % germination of their stored seeds as acceptable for sowing.

Table 15: Minimum percentage of germination considered acceptable for planting by farmers

Germination percentage considered accepted by farmers	N = 66	Percent
40		1.5
60		3.0
70		13.6
80		37.9

85	1.5
90	40.9
95	1.5
Total	**100**

From Table 16, most (19.3 %) of the farmers mentioned that too much moisture in the field at the time of planting is the cause of poor germination of soybean seed and 12.7 % argued that bad seeds is the cause of poor germination the field. About 50% of the farmers could not mention the cause of poor germination in the field.

Table 16: Causes of poor germination in soybean

Causes of poor germination	Frequency	Percent
No response	238	49.6
Bad seed	61	12.7
Drought	52	10.8
Pest and diseases	6	1.2
Too much moisture in the soil	92	19.3
Unfavorable storage condition	31	6.5
Total	**480**	**100**

Results of soybean farmers' perception of the effect of soybean seeds source on viability and vigour of seeds is shown in Figure 3. The results show that about 79.4 % of the farmers perceived that source of seeds have effect on viability and vigour of seeds while 20.6 % said seed source has no effect on seed viability and vigour.

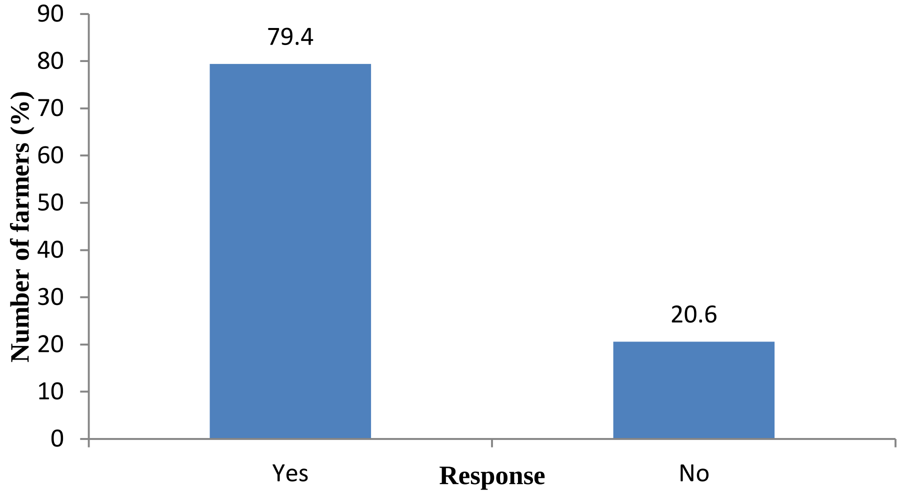

Figure 3: Seed source effect on viability and vigour of soybean seeds

From Figure 4 below, 61.3 % of the respondents said that storage method did not have an effect on the viability and vigour of soybean seeds and 39 % says storage method has an effect on soybean seeds viability and vigour.

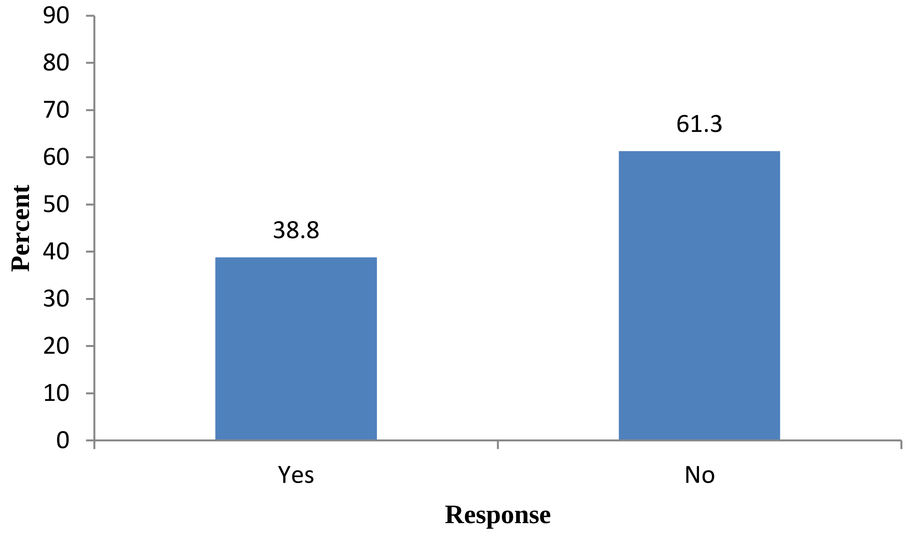

Figure 4: Storage method effect on viability and vigour of soybean seeds

4.2 Experiment 2: Field work to determine the effects of farmers' practices on viability and vigour of soybean seeds

4.2.1 Germination percentage for seeds obtained from different sources in two weeks after planting

The results of the effects of seed source on germination at 2 weeks after sowing (WAS) are presented in Table 17. The results show that there were significant ($p < 0.05$) differences in the percentage of germination among the various districts. Seeds obtained from Savelugu Municipality followed by Certified seeds had the highest germination of 68.8 % and 66.3 % respectively while seeds obtained from Tolon District had the lowest (56.6 %) percentage germination. The percentage germination of seeds from Savelugu Municipality was not statistically different from germination of seeds obtained from Certified seeds, but higher than those of seeds from Tolon and Kumbungu Districts and Yendi Municipality. There were also significant differences ($p < 0.05$) in germination percentage of seeds obtained among communities within districts as well as among farmers within communities. With regards to seeds obtained from communities in the various districts, germination percentages were not uniform. For instant Nyoglo and Challam communities in Savelugu Municipality recorded the highest percentage germination of 72.2 and 71.3 % respectively and were not significantly different but were statistically much higher than seeds from Yong community within the same district. In the case of certified seeds, seeds obtained from Heritage Seed Company and Regional Seeds Inspection Unit (RSIU) had the highest germination percentage of 72.2 % and 71.3 % respectively which were not different but significantly higher than seeds from University for Development Studies (UDS) which had the lowest (63.1 %) germination. With respect to Kumbungu District, seeds from Kpaliga community had the highest germination percentage and were different from those from Cheshegu and Chayohi communities. In Tolon Districts, seeds from Tuunaayili community had the highest percentage of germination 63.7 % and were significantly different from seeds from other communities. Similarly, in Yendi Municipality, seeds from Tusani community had the highest germination percentage of 69.2 % and statistically were different from seeds from other communities. Germination percentages of seeds obtained from farmers within communities in the same district were not uniform. For example, apart from seeds obtained from farmer 4 (f 4), seeds from all other farmers in Chayohi community in Kumbungu district were the same; seeds obtained from farmers in Cheshegu community were also not significantly different. Seeds from f 1 in Gbulahigu community in the Tolon District were significantly lower than those from other farmers. Interestingly, seeds from farmers in Tuunaayili and Yipelgu communities respectively were not statistically different. In the same way, seeds from farmers within Kulkpanga and Kushegu communities in Yendi Municipality were not significantly different from each other. However, seeds from f 2 and f 4 in Tusani community had the highest germination percentage and statistically were different from seeds from f 3. Surprisingly, except seeds from f 4 which was significantly lower in germination percentage, seeds from other farmers in Heritage were significantly higher and similar. Farmers seeds obtained from and within RSIU and UDS were statistically similar in germination percentage.

Table 17 : Field percentage germination of soybean seeds obtained from different sources at two weeks after sowing

Districts	Communities/Farmers					Mean						Mean							District Mean
Kumbungu District	Chayohi	f1 62.5	f2 58.6	f3 61.4	f4 45.7	57.1	Cheshegu	f1 69.1	f2 64.5	f3 67. 1	f4 61.3	65.5	Kpaliga	f1 71.1	f2 68.9	f3 70.4	f4 71.1	70.4	64.3
Savelugu District	Challam	f1 72.1	f2 71.6	f3 69. 5	f4 71.8	71.3	Nyoglo	f1 71.7	f2 70.2	f3 70.7	f4 76.0	72.2	Yong	f1 70.0	f2 45.7	f3 73.9	f4 70.8	65.1	69.5
Tolon District	Gbulahigu	f1 48.0	f2 58.1	f3 60.9	f4 58.1	56.3	Tuunaayili	f1 63.2	f2 64.0	f3 63.6	f4 63.9	63.7	Yipelgu	f1 50.2	f2 55.1	f3 49.9	f4 44.3	49.9	56.6
Yendi Municipality	Kulkpanga	f1 67.2	f2 61.7	f3 64.2	f4 65.3	64.6	Kushegu	f1 64.5	f2 64.5	f3 67.8	f4 63.9	65.2	Tusani	f1 68.1	f2 72.7	f3 63.9	f4 72.2	69.2	66.3
Certified Seeds (Control)	Seeds from Heritage	f1 74.0	f2 71.9	f3 76.7	f4 67.0	72.4	Seeds from R S I U	f1 74.9	f2 72.9	f3 68.9	f4 68.6	71.3	Seeds from U D S	f1 65.1	f2 65.8	f3 58.8	f4 62.6	63.1	68.8

District: L.S.D 1.857, P-Value, < .001

District*Community: L.S.D 3.216, P-Value, <.001

District *Community*Farmer L.S.D 6.432, <.001

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4.

4.2.2 Seeds source (location) effects on plant height (cm) over time for seeds obtained from different districts

Effect of source of seeds on plant height in all weeks after sowing did show significant differences ($p < 0.05$) among the various districts (Figure 5). Plants from seeds obtained from Tolon District and Yendi Municipality had the highest plant height and was similar in 1 and 2 weeks after sowing (WAS) while plants from seeds obtained from Certified seeds, Kumbungu District and Savelugu Municipality which had similar height recorded the least plant height.

Yet again, plants from seeds from Tolon District, Yendi Municipality and Certified seeds were the highest in plant height and were significantly higher in 3 and 4 WAS as compared to plants from seeds in Kumbungu District and Savelugu Municipality. (Appendix 2 A and B)

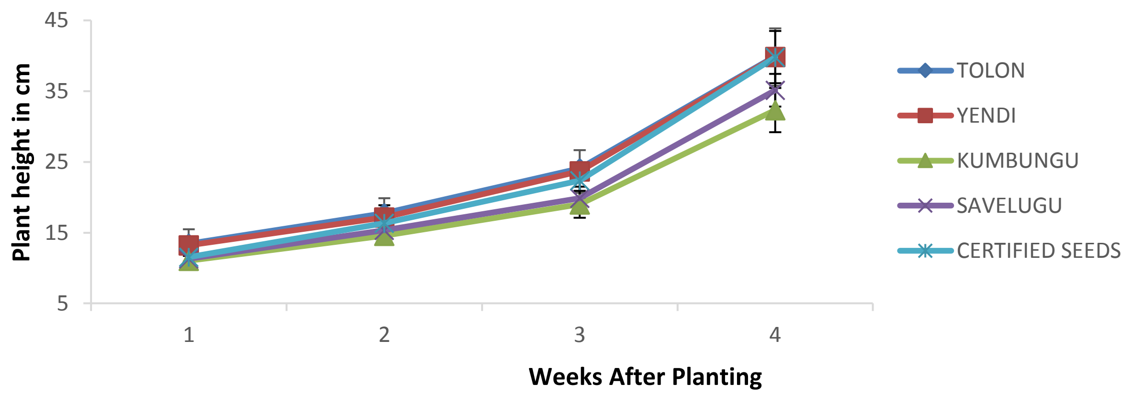

Figure 5: Plant height over time for seeds obtained from different sources
NB: Error bars represent standard deviation +/- 1

4.2.3 Seeds source (location) effects on leaves number over time for seeds obtained from different districts.

The results of the effect of seed source on number of leaves over time are presented in Figure 5. The results indicate significant differences ($p < 0.05$) among the various districts. Plants from seeds obtained from Tolon District had the highest number of leaves at 1 and 2 WAS which was significantly higher than the other Districts. However, plants from seeds obtained from Savelugu and Yendi Municipalities produced the least number of leaves at 1 WAS which were also similar at 2 WAS; plants from seeds from Kumbungu district had the least number of leaves.

Similarly, plants from seeds obtained from certified seeds and Tolon District registered the highest number of leaves at 3 and 4 WAS and were statistically the same but significantly higher than the other districts. Plants from seeds from Kumbungu District produced the lowest number of leaves. (Appendix 3 A and B)

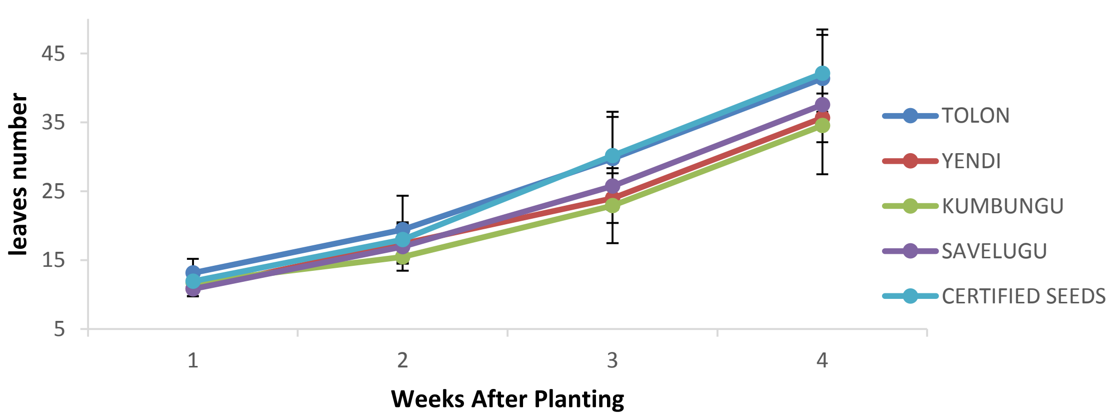

Figure 6: leave number over time for seeds obtained from different sources
NB: Error bars represent standard deviation +/- 1

4.2.4 Location (district) effects on plant height over time for seeds obtained from different communities

Among the certified seeds (controls), significant differences ($p > 0.05$) were not observed in plant height among seed growers (Heritage, RSIU and UDS) at 1, 3 and 4 weeks after sowing. However, plants from seeds obtained from UDS produced the tallest plants (17.2 cm) at 2 WAS and was significantly different from plants from seeds obtained from Heritage Seed Company which had the least plant height of (14.9 cm) (Figure 7).

Figure 8 shows that significant differences ($p > 0.05$) were not recorded among the various communities within Kumbungu district at 1, 2, and 3 WAS. However, at 4 WAS plants from seeds obtained from Chayohi community registered the highest plant height (34.5 cm) which was significantly higher than plants from seeds from Cheshegu (30.7 cm) and Kpaliga (30.2 cm) communities.

In Savelugu Municipality, significant differences ($p > 0.05$) were not observed in plant height among seeds from plants obtained from communities throughout the four weeks. (Figure 9)

In Tolon District, significant differences ($p < 0.05$) were registered in plant height among the various communities (Figure 10). Plants obtained from seeds from Tuunaayili community performed better throughout the 4 WAS and was statistically different from Gbulahigu and Yipelgu communities.

In Yendi Municipality (Figure 11), significant differences ($p < 0.05$) were observed in plant height among the various communities at 1 and 3 WAS. Kulkpanga and Tusani communities registered the highest plant height (13.9 cm) and (13.5 cm) respectively and were significantly higher than Kushegu community (12.2 cm) at 1 WAS. Moreover, Tusani and Kushegu communities also produced the greatest significance values (23.7 cm) and (23.2 cm) correspondingly which were significantly higher than Kulkpanga (21.2 cm) community at 3 WAS. At 2 and 4 WAS plants height obtained from seeds from all the communities were non-significant.

The study again further revealed no significant difference ($p > 0.05$) among seeds obtained from farmers in the same communities in the same district. (Appendix 4)

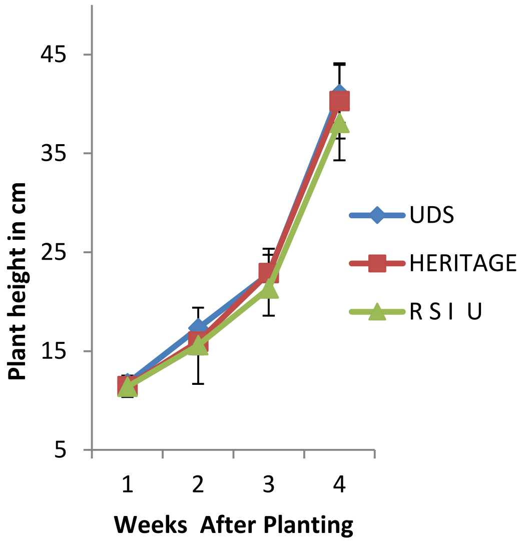

Figure 7: Plant height of plants from seeds obtained from growers in certified seeds
NB: Error bars represent standard deviation +/- 1

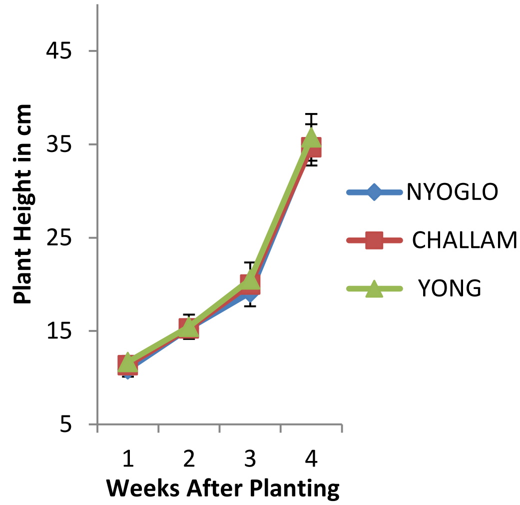

Figure 9: Plant height of plants from seeds obtained from farmers in communities in Savelugu
NB: Error bars represent standard deviation +/- 1

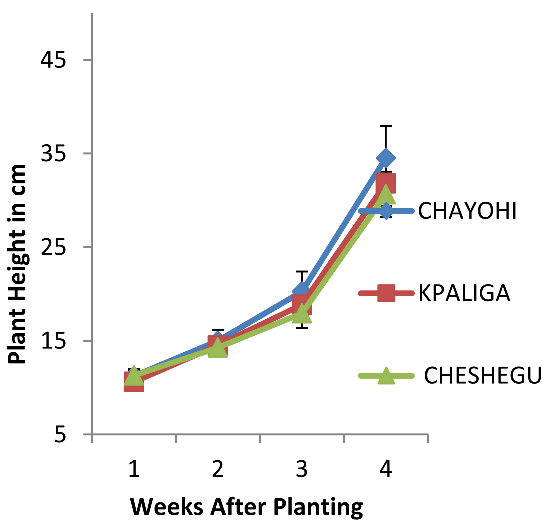

Figure 8: Plant height of plants from seeds obtained from farmers in communities in Kumbungu
NB: Error bars represent standard deviation +/- 1

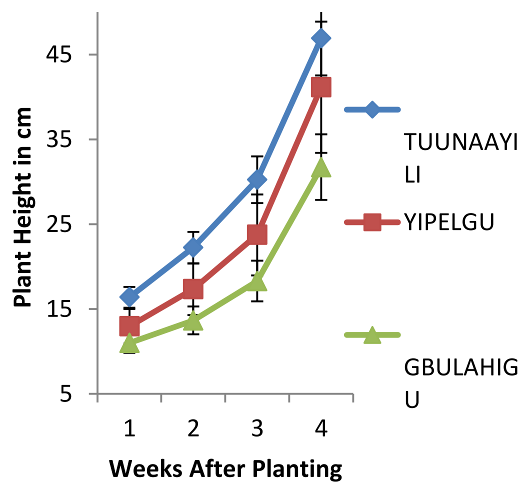

Figure 10: Plant height of plants from seeds obtained from farmers in communities in Tolon
NB: Error bars represent standard deviation +/- 1

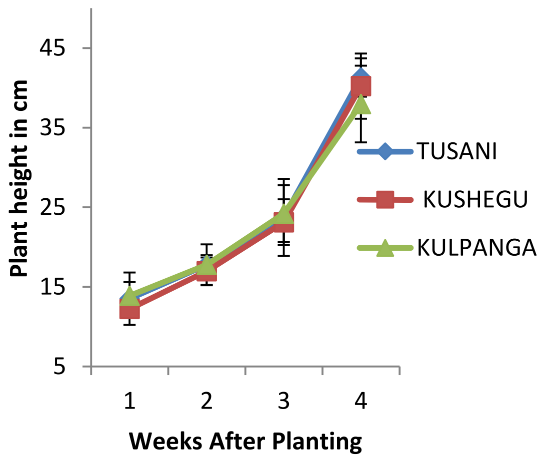

Figure 11: Plant height of plants from seeds obtained from farmers in communities in Yendi Municipality

NB: Error bars represent standard deviation +/- 1

4.2.5 Location (district) effects on leaves over time for seeds obtained from different communities

There was significant difference ($p < 0.05$) in number of leaves in weeks after sowing over time among growers in Certified seeds as shown in (Figure 12). At 1 WAS, plants from UDS seeds registered the highest (12.1) number of leaves and was statistically higher than plants from Heritage (11.9) and RSIU (11.8). Similarly, at 2 WAS plants from seeds from UDS and Heritage produced the highest (18.9) and (18.3) number of leaves and were equal but significantly higher than plants from seeds from RSIU which had the lowest (16.6). Statistically, at 3 and 4 WAS, plants from seeds from Heritage, RSIU and UDS had similar number of leaves.

Figure 14 shows significant differences ($p < 0.05$) in number of leaves among communities in the Kumbungu District during the first 4 WAS, except at week 1 where plants from seeds obtained from Chayohi community (16.6) were not different from plants from seeds from Cheshegu community (15.3).

In Savelugu Municipality, significant differences ($p < 0.05$) were recorded among communities at 1 and 2 WAS. Yong community produced the highest number of leaves and was significantly greater than plants from seeds from Nyoglo and Challam communities during 1 and 2 WAS. At 3 and 4 WAS, all communities were equivalent statistically, (Figure 13)

There were significant differences ($p < 0.05$) among communities in Tolon District during the first 4 Weeks after sowing as indicated in (Figure 15). At 1 and 2 WAS plants from seeds from Tuunaayili community had the highest (15.3) number of leaves which was significantly higher than plants from seeds from Gbulahigu (11.2) and Yipelgu (12.9) communities. Yet again, at 3 and 4 WAS Yipelgu and Tuunaayili communities produced the highest number of leaves which were significantly higher than Gbulahigu community.

In Yendi Municipality, significant differences ($p < 0.05$) were found in number of leaves among plants obtained from communities during the first 4 WAS with plants from seeds from Tusani and Kushegu communities recording higher number of leaves while plants from seeds from Kulkpanga community produced the least number of leaves during the first 4 weeks.

The study discovered significant difference ($p < 0.05$) in leaf number among seeds from farmers in the same communities in the same district except in 1 WAS where significance was observed, see (Table 18).

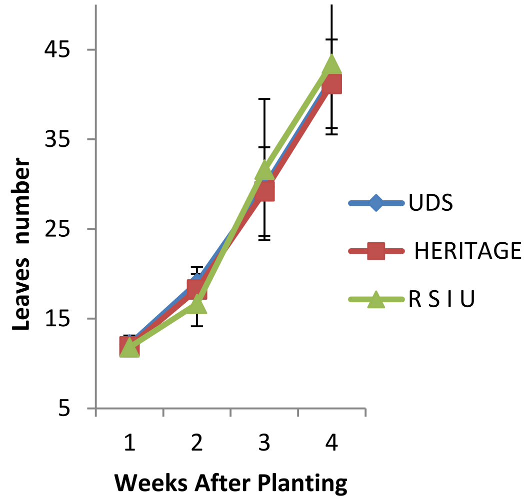

Figure 12: Leaves number of plants from seeds obtained from certified seeds
NB: Error bars represent standard deviation +/- 1

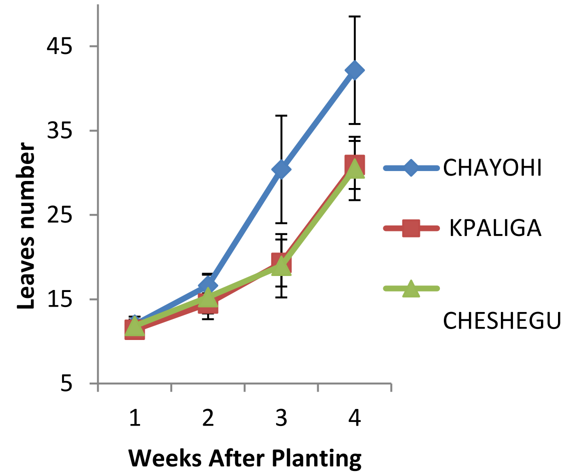

Figure 14: Leaves number of plants from seeds obtained from farmers in communities in Kumbungu
NB: Error bars represent standard deviation +/- 1

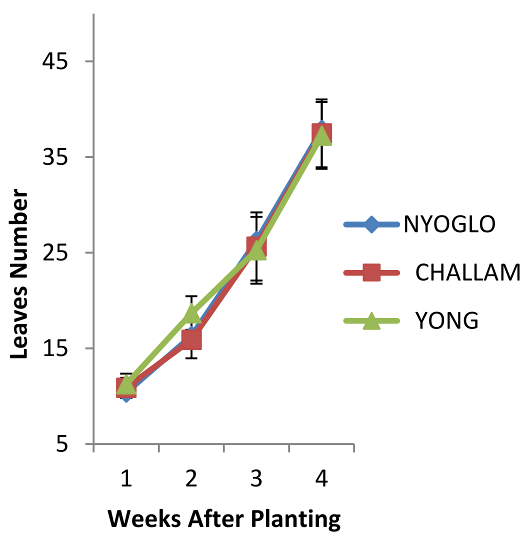

Figure 13: Leaves number of plants from seeds obtained from communities in Savelugu
NB: Error bars represent standard deviation +/- 1

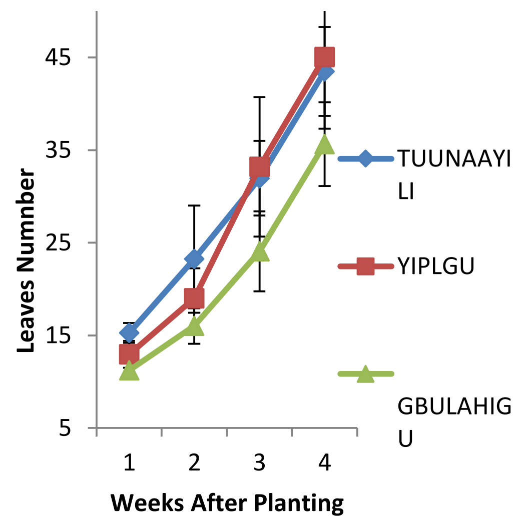

Figure 15: Leaves number of plants from seeds obtained from farmers in in Tolon
NB: Error bars represent standard deviation +/- 1

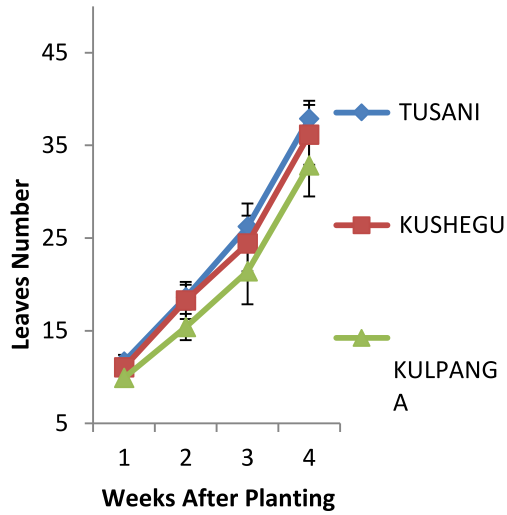

Figure 16 : Leaves number of plants from seeds obtained from farmers in communities in Yendi
NB: Error bars represent standard deviation +/- 1

Table 18: Location (District) effects on number of leaves at four week after sowing for seeds obtained from different farmers

District	Farmers														
	Community	f1	f2	f3	f4	Community	f1	f2	f3	f4	Community	f1	f2	f3	f4
Kumbungu District	Chayohi	11.9	12.0	11.8	12.3	Cheshegu	11.9	12.1	12.3	11.2	Kpaliga	11.1	11.2	11.1	12.1
Savelugu District	Challam	9.8	11.3	10.9	11.5	Nyoglo	10.6	11.4	9.7	9.9	Yong	12.6	10.3	10.9	11.2
Tolon District	Gbulahigu	11.9	11.7	11.1	10.2	Tuunaayili	15.0	15.4	16	14.7	Yipelgu	12.7	13.0	13.2	12.9
Yendi Municipality	Kulkpanga	9.7	10.1	10.1	9.8	Kushegu	11.7	10.8	11.4	10.3	Tusani	11.3	12.4	11.9	11.1
Certified Seeds (Control)	Seeds from Heritage	11.6	11.5	11.2	13.1	Seeds from R S I U	11.6	11.5	11.9	12.1	Seeds from U D S	12.3	12.1	12.3	11.8

District *Community* Farmers': L.S.D, 1.2709 , P-Value, 0.009

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4

The results of the effect of location on soybean dry shoot weight at 4 WAS are presented in Table 19. There were significant differences ($p < 0.05$) in the dry shoot weight of plants from seeds obtained from different districts and communities in the same district. Plants from seeds from Tolon District had the highest dry shoot weight of (139.7 g) and significantly different from the dry shoot weight of plants from seeds obtained from other Districts. Plants of seeds obtained from Kumbungu District had the lowest dry shoot weight of (71.5 g) which was similar to those of seeds from Savelugu Municipal (80.2 g). Dry shoot weight of plants from Certified seeds as well as those from Yendi Municipality were similar. In some Districts, there were unevenness in dry shoot weight and significant differences among communities. Plants from seeds from Tuunnayili community in Tolon district had the greatest dry shoot weight of (175 g) and were significantly greater than dry shoot weight of plants from Gbulahigu (68.7 g) and Yipelgu (150.1 g) communities. Plants from seeds obtained from Chayohi community in Kumbungu District had significantly greater (87.6 g) dry shoot weight than dry shoot weight of plants from seeds from Kpaliga community which was statistically lower (58.2 g). Similarly, Yong community in Savelugu District produced the highest dry shoot weight which was significantly higher (101.2g) than Challam (68.7 g) and Nyoglo (70.6 g) communities. In the same way, dry shoot weight of plants from Kushegu community in Yendi Municipality recorded the highest (118.3 g) value which was statistically higher than those of plants of seeds obtained from Kulkpanga community which had the least value (90.1 g). Interestingly, dry shoot weight of plants from Heritage, RSIU and UDS seeds were not different. The results additionally revealed that generally, there were no significant differences in dry shoot weight among seeds from farmers within communities in the same district.

Table 19: Location (District) effects on dry shoot weight (g) at nine weeks after sowing for seeds obtained from different sources

	Communities/Farmers															
District					Mean					Mean						District Mean
Kumbungu	Chayohi					Cheshegu					Kpaliga					
District	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	90.6	96.7	76.2	86.9	87.6	66.7	56.3	77.7	73.9	68.7	58.2	56.4	55.6	62.5	58.2	71.5
Savelugu	Challam					Nyoglo					Yong					
District	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	54.6	69.2	76.9	74	68.7	70.7	83.3	62.9	65.6	70.6	119.8	141.3	71.2	72.5	101.2	80.2
Tolon	Gbulahigu					Tuunaayili					Yipelgu					
District	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	95.5	101.3	95.7	83.9	68.7	184	168.4	196.8	150.8	175	152	161.6	154.9	131.7	150.1	139.7
Yendi	Kulkpanga					Kushegu					Tusani					
Municipality	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	72.7	94.7	125.8	67	90.1	127.5	103.9	125.7	116.2	118.3	94.3	130.4	127	76.6	107.1	105.1
Certified	Seeds from Heritage					Seeds from R S I U					Seeds from U D S					
Seeds	f1	f2	f3	f4		f1	f2	f3	f4		f 1	f2	f3	f4		
(Control)	108.7	97.4	99.3	125	107.9	118.2	102.5	108.2	122.6	112.9	135	126.5	188.6	121.4	125.4	115.4

District: L.S.D 13.57, P-Value, < .001,
District*Community: L.S.D: 23.50, P-Value, <.001,
District*Community*Farmers': L.S.D 47.00, P-Value, 0.584.
Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4

There were significant differences ($p < 0.05$) in dry root weight of plants from seeds obtained from various districts, among communities within district as well as farmers' in the same communities in the same district (Table 20). Plants from seeds obtained from Tolon District registered the greatest (15.7 g) root dry weight which was statistically greater than that of other districts. Dry root weight of plants of seeds from Savelugu Municipality (10.1 g) and Yendi Municipality (10.9 g) were similar but significantly lower than the rest of the districts. With regards to communities in the same districts, dry root weights were not uniform. Plants from seeds from Tuunaayili and Yipelgu communities in Tolon district recorded the highest (17.1 g) and (16.4 g) root dry weight which were significantly while dry root weight of seeds from Gbulahigu community recorded the least (13.7 g) and was significantly lower. In savelugu Municipal, dry root weight of plants of seeds from Challam community in Savelugu (7.9 g) was not significantly different from those from Nyoglo (8.4 g) community. Within the certified seed category, dry root weight of plants of seeds from UDS was the highest (13.9 g) which were significantly greater than dry root weight of plants of seeds from Heritage (10.7 g) and RSIU (10.7 g) which were similar. Similarly, Cheshegu community in Kumbungu district was also not different from Kpaliga. Equally Kulkpanga community in Yendi Municipality was the same as Kushegu community. The study further discovered significance difference in dry root weight of plants from seeds among farmers within communities in the same location. However, seeds from farmers in Heritage seed grower, RSIU and UDS were not significantly different. Apart from seeds from f 1 in Chayohi community in Kumbungu District which dry roots were statistically different from seeds from f 2, plants from other farmers were significantly similar. Seeds from farmers from Cheshegu and Kpaliga communities had the same dry root weight. Additionally, farmers in Challam and Nyoglo communities in Savelugu Municipality were not different. On the other hand, f 1 and f 2 in Yong community had similar dry root weight but significantly different from those of seeds from other farmers. Also, seeds from f 2 and f 3 in Gbulahigu community in the Tolon District were different from other farmers as far as dry root weight is concerned. However, seeds from farmers in Tuunaayili and Yipelgu communities were similar. Seeds from farmers in the Tusani community in Yendi Municipality also had similar dry root weight.

Table 20: Dry root weight (g) at nine weeks after sowing of plants of seeds obtained from different sources

District	Communities/Farmers				Mean					Mean						District Mean
Kumbungu District	Chayohi					Cheshegu					Kpaliga					
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	14.9	10.0	11.5	13.5	13.5	12.5	10.3	15.2	11.6	12.4	11.5	9.9	9.7	11.4	10.6	12.8
Savelugu District	Challam					Nyoglo					Yong					
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	6.6	8.5	7.1	9.4	7.9	9.4	9.3	7.3	7.3	8.4	15.5	19.8	10.7	9.9	13.9	10.1
Tolon District	Gbulahigu					Tuunaayili					Yipelgu					
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	12.3	15.9	15.8	10.7	13.7	15.8	17.7	18.3	16.8	17.1	15.7	16.5	18.2	15.3	16.4	15.7
Yendi Municipality	Kulkpanga					Kushegu					Tusani					
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	8.8	12.1	13.9	10.9	11.4	19.4	10.2	12.7	10.8	13.3	7.1	10.1	9.7	5.9	8.2	10.9
Certified Seeds (Control)	Seeds from Heritage					Seeds from R S I U					Seeds from UDS					
	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	9.3	10.6	10.8	12.2	10.7	9.8	10.6	11.1	11.2	10.7	13.7	13.7	14	14.2	13.9	11.8

District: L.S.D 1.223, P-Value, < .001

District* Community: L.S.D 2.117, P-Value, <.001

District*Community*Farmers': L.S.D 4.235, P-Value, <.001.

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4.

Table 21 shows location effects on vigour index of plants from seeds from various districts, communities as well as farmers'. Significant differences ($p < 0.05$) were observed in vigour index of plants from seeds obtained from the various districts. Vigour index of plants obtained from seeds from Yendi Municipality had the highest value, which was statistically greater than that of other districts. However, vigour index of plants from seeds obtained from Savelugu Municipality and Tolon district were statistically similar. For communities in districts, vigour index of plants from seeds obtained from Chayohi community in Kumbungu District were significant with f 4 being lower than the rest. Again, in Savelugu Municipal, vigour index of plants from seeds acquired from Nyoglo community were significantly different from plants from seeds obtained from Challam and Yong communities whose values were statistically the same. Additionally, vigour index of plants from seeds obtained from communities in Tolon District were statistically different from each other except those from seeds obtained from Gbulahigu and Yipelgu communities were similar. Similarly, vigour index of plants from seeds obtained from communities in Yendi Municipality were statistically different however vigour index of plants from seeds obtained from Kulpanga and Kushegu communities were similar. In the case of certified seeds, vigour index of plants from seeds obtained from RSIU and UDS were significantly different from each other however. The study further revealed significant difference in vigour index of plants from seeds obtained from farmers within communities in the same district. Within the Certified seed category, Vigour index of plants from seeds acquired from farmers' in Heritage Seed Company were statistically similar. Again, vigour index of plants from seeds obtained from farmers' in RSIU were all statistically similar except that those from f 1 and f 2 as well as f 1 and f 3 were significantly different, in the same way, vigour index of plants from seeds from farmers' in UDS were statistically the same. However, those from f 1 were statistically different. Furthermore, vigour index of plants from seeds from farmers' in Chayohi community in the Kumbungu district were non- significant with the exception of vigour index of plants from seeds from f 1 and f 4, f 2 and f 4 as well as f 3 and f 4 which were significantly different. Yet still vigour index of plants from seeds from farmers' in Cheshegu and Kpaliga communities were statistically similar. Additionally, vigour index of plants from seeds from farmers' in Challam and Nyoglo communities in the Savelugu Municipality were identical statistically. Likewise, vigour index of plants from seeds from farmers' in Yong community were significantly the same except that vigour index of plants obtained from seeds from f 1 and f 2, f 2 and f 3 as well as f 2 and f 4 were significantly different. Equally, vigour index of plants from seeds from farmers' in Gbulahigu community in Tolon district were statistically similar, excluding vigour index of seeds from plants from f 1 and f 2, f 1 and f 3 as well as f 1 and f 4 which were significantly different from each other. Again, vigour index of plants from seeds from farmers' within Tuunaayili community were statistically similar. In the same way, vigour index of plants from seeds from farmers' in Yipelgu community were statistically the same, apart from vigour index of plants from seeds from f 2 and f 4 as well as f 3 and f 4 which were significantly different. Additionally, with the exception of vigour index of plants from seeds obtained from f 1 and f 3, f 2 and f 3 as well as f 3 and f 4 which were statistically different in Yendi Municipality, vigour index of plants from seeds from all other farmers were statistically the same. However, in the case of vigour index of plants from seeds from farmers in Kushegu community, significance differences were not observed. Finally, with the exception of vigour index of plants from seeds from f 1and f 3, f 2 and f 3 as well as f 2 and f 4 where significant differences were obtained, vigour index of plants from seeds from other farmers were statistically similar.

Table 21: Vigour index of seeds obtained from different sources at nine weeks after sowing

	Communities/Farmers																		
Districts						Mean (10^2)						Mean (10^2)							District Mean (10^2)
	Community	f1	f2	f3	f4		Community	f1	f2	f3	f4		Community	f1	f2	f3	f4		
Kumbungu District	Chayohi	37.9	34.4	35.0	22.4	32.5	Cheshegu	36.4	32.7	37.5	32.3	34.7	Kpaliga	37.5	32.7	37.5	32.3	37.6	34.9
Savelugu District	Challam	39.7	40.6	42.3	42.9	41.4	Nyoglo	44.7	40.3	42.2	39.1	41.6	Yong	44.7	20.7	41.7	40.6	36.9	39.9
Tolon District	Gbulahigu	20.3	31.9	31.8	31.9	29.0	Tuunaayili	54.4	52.4	56.7	52.3	53.9	Yipelgu	33.7	38.8	33.0	24.2	32.4	38.5
Yendi Municipality	Kulkpanga	47.8	46.3	57.7	45.3	49.3	Kushegu	56.2	49.7	53.6	47.7	51.7	Tusani	63.6	83.4	60.4	66.3	68.4	56.5
Certified Seeds (Control)	Seeds from Heritage	54.6	47.3	48.2	47.8	49.5	Seeds from R S I U	57.2	47.5	44.9	51.3	50.3	Seeds from U D S	50.1	48.2	39.9	43.7	45.5	48.4

District: L.S.D 2.63, P-Value, < .001

District* Community: L.S.D 4.55, P-Value, <.001

District* Community*Farmer L.S.D 9.10, <.001

NB: Higher value means higher seed vigour

4.3 Experiment 3: Laboratory experiment to determine the effects of farmers' practice on viability and vigour of soybean seeds

Table 22 shows the results of the laboratory germination test over time. Significant differences ($p < 0.05$) were observed in the germination of seeds from among the various districts. Seeds from Yendi Municipality had the highest germination percentage after 10 days of laboratory experiment and were significantly different from seeds from the other districts whereas Tolon District had the lowest. Germination of seeds from Kumbungu District was not statistically different from those of seeds from Savelugu Municaplity. Also, there was significant difference in percentage of germination of seeds obtained from communities in the same districts. The results further revealed significant difference in seeds from farmers in the same communities in the same district. The results of the laboratory germination test indicate the mean percentage germination ranged from 66.2 % with seeds from Tolon district to 79.7 % for seeds from Yendi Municipality with significant differences ($p < 0.05$) between the districts. There were also significant differences in germination of seeds from different communities within the same districts. In Savelugu Municipality, seeds from Nyoglo community recorded the highest germination percentage of 78 while those from Challam community recorded the lowest germination percentage of 68.7 but the percentage germination of seeds from Challam community was not significantly different from that of seeds from Yong community. In Yendi Municipality seeds from Kushegu community recorded the highest germination whereas seeds from Kulkpanga community recorded the lowest germination but the percentage germination of seeds from Kulpanga community was not statistically different from those of Tusani community.

Table 22: Location (District) effects on laboratory germination at ten days for soybean seeds obtained from different sources

District	Communities/Farmers				Mean					Mean						District Mean
Kumbungu	Chayohi					Cheshegu					Kpaliga					
District	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	74.2	64.7	72.2	52.1	66.1	73.4	74.7	73.5	58.1	69.9	79.9	81.8	81.4	79.6	80.7	72.2
Savelugu	Challam					Nyoglo					Yong					
District	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	66.3	72.6	67.5	69.5	68.9	76.8	79.8	76.8	78.6	78.0	75.9	53.1	75.4	72.9	69.3	72.1
Tolon	Gbulahigu					Tuunaayili					Yipelgu					
District	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	52.2	72.3	53.9	60.8	59.8	70.1	76.5	72.8	80.6	74.9	67.9	67.9	57.0	62.4	63.8	66.2
Yendi	KulKpanga					Kushegu					Tusani					
Municipality	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
	77.6	74.2	77.5	77.5	76.5	81.6	81.4	84.6	78.9	82.4	80.1	82.0	81.0	76.9	79.9	79.7
Certified	Seeds from Heritage					Seeds from R S I U					Seeds from UDS					
Seeds	f1	f2	f3	f4		f1	f2	f3	f4		f1	f2	f3	f4		
(Control)	79.7	79.4	66.3	67.8	73.3	74.2	72.9	67.7	69.2	70.9	68.3	66.5	61.2	63.8	64.9	69.7

District: L.S.D 1.695, P-Value, < .001

District* Community: L.S.D 2.936, P-Value, <.001

District*Community*Farmers: L.S.D 5.872, <.001

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4

Table 23 presents the results of vigour index of plants from seeds obtained from different sources. Significant differences ($p < 0.05$) were observed in vigour index of plants from seeds obtained from among the districts. Plants from seeds from Yendi Municipality had the highest vigour index and were statistically different from those of seeds from other districts. However, vigour index of plants from seeds obtained from Tolon district was the lowest. In the case of communities within districts, vigour index of plants from seeds obtained from Chayohi community in Kumbungu District were significantly lower as compared to other two (kpaliga and Cheshegu) communities. For Savelugu Municipality, vigour index of plants from seeds from Challam was highest while Young had the lowest vigour index. For Tolon District, vigour index of plants from seeds from Tuunaayili community was significantly higher and different from others. Vigour index of plants from seeds from Gbulahigu and Yipelgu communities were similar. Plants from seeds obtained from Kushegu community in the Yendi Municipality were more vigorous as compare to the rest. Vigour index of plants from seeds obtained from Tusani and Kulkpanga communities registered lowest and were similar in vigour index. For certified seeds, vigour index of plants from seeds obtained from RSIU were statistically higher than the rest while vigour index of plants from seeds obtained from Heritage seeds grower and UDS were similar. With regards to vigour index of plants obtained from seeds from farmers within same communities, plants from seeds obtained from farmers' in Chayohi community in the Kumbungu District were statistically different, however, vigour index of plants from seeds from f 2 and f 4 were significantly similar. Plants from seeds from farmers' in Cheshegu community in the Kumbungu District were significantly different with seeds from f 4 being more vigorous than others. Additionally, vigour index of plants from seeds from farmers' in Kpaliga community were statistically similar except f 2 which was better than the others. Moreover, vigour index of plants from seeds obtained from f 2 in Challam community in the Savelugu Municipality were higher than the rest, vigour index of plants from seeds from farmers in Nyoglo community were similar in most cases, except that f 1 was significantly different from f 2 and f 4. Similarly, vigour index of plants from seeds from farmers' in Yong community were statistically different except for plants from seeds from f 3 and f 4 which were identical in vigour. Equally, plants from seeds from farmers in Gbulahigu community in the Tolon district were significantly different in vigour index with f 4 seeds being most vigorous while those from f 2 showed least vigour. Seeds from f 4 in Tuunaayili community were more vigorous than the other farmers. In Yipelgu community, seeds from f 2 had the least vigour index while those from f 1 and f 4 had the highest. Vigour index of plants from seeds from farmers' in Kulpanga community in the Yendi Municipality revealed that seeds from f 4 were more vigorous as compared to those from others farmers. Likewise, vigour index of plants from seeds from farmers' in Kushegu community were statistically different with those from f 1 being more vigorous than seeds from f 3 and f 4. In Tusani community, vigour index of plants from f 1 were more vigorous than those from f 2 and f 3. Expectedly, vigour index of plants from seeds obtained from farmers' growing certified seeds from a particular seeds producer did not showed any significant difference (Table 23).

Table 23: Location (District) effects on vigour index of seeds obtained from different sources at ten days after experiment

	Communities/Farmers																		
Districts						Mean (10^2)						Mean (10^2)							District Mean (10^2)
Kumbungu District	Chayohi	f1	f2	f3	f4		Cheshegu	f1	f2	f3	f4		Kpaliga	f1	f2	f3	f4		
		14.4	67.0	12.97	66.6	10.2		16.9	16.9	16.8	97.3	15.1		12.5	21.4	13.4	15.4	15.7	13.7
Savelugu District	Challam	f1	f2	f3	f4		Nyoglo	f1	f2	f3	f4		Yong	f1	f2	f3	f4		
		14.5	19.4	12.6	14.0	15.3		10.4	14.2	12.4	14.2	12.8		14.9	43.1	10.3	11.4	10.3	12.7
Tolon District	Gbulahigu	f1	f2	f3	f4		Tuunaayili	f1	f2	f3	f4		Yipelgu	f1	f2	f3	f4		
		63.4	11.8	51.1	76.6	77.3		12.4	13.7	12.9	17.4	14.1		92.8	11.8	56.9	93.3	90.2	10.3
Yendi Municipality	Kulkpanga	f1	f2	f3	f4		Kushegu	f1	f2	f3	f4		Tusani	f1	f2	f3	f4		
		12.6	15.6	15.4	20.2	15.9		24.3	23.5	20.8	19.6	22.0		19.3	15.9	15.8	16.9	16.9	18.3
Certified Seeds (Control)	Seeds from Heritage	f1	f2	f3	f4		Seeds from R S I U	f1	f2	f3	f4		Seeds from U D S	f1	f2	f3	f4		
		12.5	14.2	11.0	11.5	12.3		15.1	16.8	15.3	18.0	16.3		11.7	10.1	10.9	12.3	11.3	13.3

District: L.S.D 0.93, P-Value, < .001 NB: Higher value means higher seed vigour

District* Community: L.S.D 1.61, P-Value, <.001

District*Community*Farmer L.S.D 3.23, <.001

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer

CHAPTER FIVE

5.0 DISCUSSION

5.1 Experiment 1: Survey to determine how farmers' store soybean seeds

5.1.1 Age distribution of soybean farmers

Age plays a significant role in productivity of agriculture as both youth and old are in the front line of farming in the area. The age ranges of respondent's shows that majority (48.1 %) of the soybeans farmers are within the age range of 35 - 60 years. However, a sizeable number of the farmers (40.6 %) also fall within the youth bracket (18-35 years) which is encouraging as young people are able to withstand stress and spend more time in field activities which can lead to higher productivity. Only few (11 %) of aged farmers are involved in soybean production, probably due to the volume of work involved in its production. Soybean is an early maturing crop which brings a quick return on investment and therefore very attractive to the youth.

5.1.2 Educational level of soybean farmers

Responses from the survey indicated that majority (73.8 %) of farmers who were into soybeans cultivation in northern Ghana were illiterates. However, this phenomenon is typical in Africa and particularly in northern Ghana where agriculture is basically subsistence and make up a greater proportion of the livelihoods of the rural people who are often not educated. Only 10 % of farmers had Senior High School or higher education. This development is seriously affecting agricultural productivity since most of our illiterate farmers are not aware of good storage practices and many other issues regarding postharvest handling and storage of crops especially commercial crops such as Soybeans. According to Appleton and Balituita (1996) and Weir (1999), education offers substantial benefits to farmers in terms of productivity gains. This indeed also greatly affects agricultural technology adoption on the part of farmers.

5.1.3 Arable land available for farming

The study indicates that majority of the farmers in Northern Region practice basically subsistence agriculture. One hundred and twelve respondents representing 70 % possess a land area of less than 5 hectares for farming. The reason could be that soybeans is not considered as a major staple food and perhaps farmers allocate meager part of their farm land for its cultivation in Northern Region and Ghana as a whole. In Ghana, most farmers use smaller acreage (0.25 to 2 ha) of land usually for soybean cultivation (Asafo-Adjei et al., 2005).

5.1.4 Experience in the cultivation of soybean

The survey shows 43 % of the soybean farmers went into the production of soybeans less than 5 years ago. Thirty two percent of the farmers have been cultivating soybean for 5-10 years. Although soybeans was first introduced in Ghana in 1909 (Mercer-Quarshie and Nsowah, 1975), it was during the last decade that its production assumed commercial status due to availability of market for the grain and promotion of the crop by Ministry of Agriculture and other Non-Governmental Organizations.

5.1.5 Criteria for selecting soybean for planting by farmers

The choice of variety of soybean for cultivation by farmers in Northern Region is based on its shattering ability. The study revealed that 58.1 % were into the production of non-shattering variety of soybean (Jenguma) and 28.8 % farmers were into this same variety for its high yielding ability. According to Dugje et al. (2009), the Jenguma (TGX 1448-2E) variety of soybean is recommended for the southern and northern Guinea savannas agro-ecological zones of West Africa for cultivation due to its desirable characteristic including its medium maturity, high yield, low shattering, high oil content and excellent grain color. Soybean variety selection by farmers is based on maturity, yield potential, lodging, drought tolerance, and resistance to pests and diseases. It was expected the maturity period should have been the first consideration when farmers are choosing a variety suited to their geographical zone. Normally, varieties that are early maturing rather than late maturing are considered in areas with low rainfall. It is too risky to cultivate late-maturing varieties in drier locations because of late-season drought even though later maturity increases yield potential (Dugje et al., 2009).

5.1.6 Number of year for cultivating the variety

Evidence from the study shows that soybean farmers in Northern Region went into the cultivation of “Jenguma” in recent time. Majority (50.1 %) went into the production of “Jenguma” in recent times. However, soybean production started seriously in Ghana in the early 1970s. This was due to collaborative breeding efforts of Ghana’s Ministry of Food and Agriculture (MOFA) and the International Institute of Tropical Agriculture (IITA) (Tweneboah, 2000).

5.1.7 Proportion of total soybean used for home consumption and for sale

The study shows majority (83 %) of the farmers use small part of their harvested grains of soybeans for home consumption and most part for sale. Although soybean has high nutritional value in terms of protein, very little is consumed by farmers who produce the crop partly due to lack of knowledge in the processing of the crop. Soybean is among the main industrial and food crops grown in all continents (Dugje et al., 2009). The need to incorporate it into traditional diet should be emphasied.

5.1.8 Challenges in soybean cultivation

Responses from the study indicate that pest and diseases incidence is the most important challenge faced by soybean farmers in the Northern Region of Ghana. Other major challenges are access to input (14.4 %) and output (26 %) market. Surprisingly, a hand full (1.2 %) of the farmers said seed viability has been a challenge. From experience, farmers were of the view that if soybeans are stored for more than one year, it would not be worthless for planting simple because it loses its viability. This agrees with the work of Gupta and Aneja (2004), who reported that one of the main limitations of soybean cultivation is the availability of less vigorous seeds at planting time. Perception by farmers that disease and insect pests are the major challenge in soybean cultivation is surprising because according to Asafo-Adjei et al. (2005), soybean to certain degree is a new crop in Ghana and hence hardly 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. Furthermore, Dugje et al. (2009) also reported that, though several different insects occur in soybean fields, few are normally of any economic importance and the species that cause damage are usually not abundant enough to warrant control measures. In the vegetative stage, the crop is very tolerant of caterpillars but very susceptible to silver leaf whitefly attack. From flowering onwards, soybean becomes attractive to pod-sacking bugs that can seriously reduce seed quality. Soybean diseases normally result in major yield losses in Nigeria. Some of the common diseases of soybeans are caused by fungi, bacteria and virus. However, some of these diseases are not yet common in Ghana.

5.1.9 **Soybean storage**

From the study, almost all (99 %) of the farmers store soybean seeds on their own for planting in the next season and only 1% of the farmers rely on seeds from their neighbours. Dugje et al. (2009), recommend that farmers should not purchase seeds from the open market as the germination potential is not guaranteed. Planting poor quality seeds will not produce a good yield. As found in many other crops, most smallholder farmers in Ghana hardly purchase certified seeds for planting partly due to accessibility. In most rural areas in Northern Ghana, many farmers must travel several kilometers to the regional capital before they could get certified seeds to buy. Hence, they prefer saving their own seeds for planting during the following season.

5.1.10 Methods of storage of seeds by soybean farmers

The survey indicates that 61.3 % of soybeans farmers store their seeds in sacks placed on top of wooden material and 22.5 % store their seeds in sacks and placed on the bare floor. Dugje et al. (2009) suggest that 50-kg or 100-kg bags of clean soybean should be placed on a rack in the cold room or in shade. High moisture content in stored soybean encourages the development of various agents of deterioration, such as insects and microorganisms. Good storage management can greatly influence the storability of soybean and subsequent germination when planted in the field. Efforts should be made to ensure that soybean seeds are not exposed to high temperatures, as it will increase deterioration and reduce seed viability.

5.1.11 Seeds germination, test for viability or vigour potential

Responses from this study show that quite a number (58.7 %) of the farmers did not carry out any germination test on their stored soybeans seeds before planting. Farmers should be encouraged to test seeds for viability before planting, as this will ensure planting of quality seeds ensure high low yield. Pratt et al. (2009) reported that in storage, soybean seed quickly loses its viability and a germination test is essential to determine viability and vigour. Similarly, Van-Gastel et al. (1996) also stated that percentage germination is determined by performing a germination test. Failure in germination may lead to total crop failure.

5.1.12 Germination percentage recorded in the year 2015 by farmers

The results of the study revealed that about 46 % of the soybean farmers recorded 90 % and above germination rate of their stored seeds used for sowing in the 2015 cropping season during their seed testing before sowing in the field (Table 14). Farmers need to conduct seeds test in other to be sure of good germination in the field and the higher germination obtained by the farmers may be due to the fact seeds were stored less than one. Viability and vigour of soybean seeds reduces normal after one year. Pratt et al. (2009) reported that soybean seed with good germination of 80 % as a minimum and free of weed seed, trash, and damaged beans are recommended to be used for planting.

5.1.13 Minimum percentage of germination considered acceptable for planting by farmers

According to the study, twenty-even (27) respondents representing 40.9 % considered 90 % germination of their stored seeds as acceptable for sowing. This could be attributed to the perception of farmers that seed source has effect on viability and vigour of seeds. This observation corroborates with the statement of Dugje et al. (2009) who stated that germination test of seeds should be carried out prior to planting; the rate of germination should be above 85 % to obtain a good stand.

5.1.14 Causes of poor germination in soybean

The study did indicate that (19.3 %) of the farmers mentioned that too much moisture in the field at the time of planting would result in poor germination of soybean seed. This assertion by the farmers confirms the recommendation by (Dugje et al., 2009) that soybean should not be grown in waterlogged soils or soils with surfaces that can crust, as this could lead to poor seedling emergence, (Dugje et al., 2009). There are two critical periods for soybean moisture requirement; from sowing to germination and flowering, and pod filling periods. During germination, the soil needs to be between 50 % and 85 % saturated with water, as the seed absorbs 50 % of its weight in water before it can germinate (Rienke and Joke, 2005) and (Addo-Quaye et al., 1993).

5.1.15 Farmers' perception of the effect of soybean seeds source on viability and vigour of seeds

The study further revealed soybean farmers' perception of the effect of soybean seeds source on viability and vigour of seeds. The results did show that about 79 % of the farmers perceived that source of seeds have effect on germination, viability and vigour of seeds. Soybean grows in diverse agro-ecological conditions; therefore seed germination and vigour are affected by numerous unfavorable environmental influences such as drought, extreme temperatures, untimely sowing, etc. (Casenave & Toselli 2007). It is common for soybean, even when stored properly, not to germinate after 12 –15 months in storage, it easily loses its viability. Therefore, it is appropriate for farmers indeed to use seeds which have not been stored more than 12 months old to ensure good germination.

Farmers are advised not to purchase seeds from the open market as the germination potential is not guaranteed.

5.1.16 Seed storage method effect on viability and vigour of soybean seeds

The study shows that majority (61.3 %) of the respondents were of the view that storage method does not have effect on viability and vigour of soybean seeds. The reason for this response from the farmers was that seeds that were immature and yet stored properly, would not germinate per their experience. This collaborates with the work of Vasudevan et al. (2008), who reported that in early harvested seed crop, the seed quality (viability and vigour) will be very poor due to more number of immature and undeveloped seeds. Similarly, Perry (1982) also reported that seed maturation is one of the main components of seed viability and vigour and a prerequisite for successful germination and emergence. Furthermore, farmers' experience of soybean easily losing its viability after 12 months of storage could also be a factor rather than how it was stored. Soybean seed is well known for its short storage life and is currently not carried-over to the next planting season (Nkang and Umoh, 1996). Also, the work of Gokhale (2009), further shows 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.

5.2 Experiment 2: Field work to determine the effects of farmers' practices on viability and vigour of soybean seeds

5.2.1 Seeds source (location) effects on germination of seeds from different districts at two weeks after sowing

There were differences in germination percentages ($p < 0.05$) among the various districts. Seeds obtained from Savelugu Municipality and certified seeds had the highest germination percentage while seeds from Tolon District recorded the lowest germination percentage. The difference in germination percentage could be attributed to the differences in weather conditions among the districts where the seeds were obtained especially during seed maturation. For instance, the locations of seeds from Savelugu Municipality and Certified seeds from Tamale metropolis had the same amount of rainfall and were the highest from September to November in the production year 2015 with 136.2 mm and 136.2 mm respectively while Tolon District had 119.8 mm. It is therefore possible that most of the seeds from Tolon developed during the tail end of the season when the rainfall was less. This observation corroborates with the work of TeKrony et al. (1980) who pointed out that soybean seed viability can be reduced by extremes in rainfall.

5.2.2 Seeds source (location) effects on vegetative growth (plant height (cm) and number of leaves) over time for seeds obtained from different districts

Variations in height of plants from seeds obtained from among the various districts were significant ($p < 0.05$) in this study. Seedlings of seeds from Tolon District, Yendi Municipality and certified seeds recorded the highest plant height, compared with seedlings of seeds from Kumbungu districts and Savelugu Municipality. This might be due to differences in micro climatic environmental conditions (light, relative humidity, soil nutrients) of the field where seeds were produced. This result conforms to the work of Padin et al. (2002) who stated that characteristics such as the environmental conditions during grain formation on plants are factors influencing vigour. Gokhale (2009) reported that fluctuations in environmental conditions during seeds production are a factor affecting seed vigour. Joshiet et al. (2009) found a significant and positive correlation of plant height with seed vigour.

Significant differences were observed in leaves number among plants obtained from the various districts. Plants of seeds obtained from Certified seeds and Tolon District recorded higher number of leaves while plants obtained from Kumbungu District recorded the least number of leaves at four weeks after sowing. The variation might have been due to the fact that seeds were obtained from difference location altogether with possible differences in micro environmental conditions. This result is similar to that of Sun et al. (2007) who found that the environment (source) where seed develops can have great influence on vigour. Environmental factors such as light, water and the kind and quantity of available nutrients may affect seed formation and development (Pallais et al., 1987).

5.2.3 Seeds source (location) effects on dry shoot and root weights (g) at nine weeks after sowing for seeds obtained from different districts

Statistically, the effect of location was observed to have a significant influence on the dry shoot weight of seedling at nine weeks after sowing. Plants from Tolon District recorded the greatest shoot weight whereas plants from Kumbungu districts and Savelugu Municpality had lower dry shoot weight. This could probably be due to variations in some natural factors such as sunshine and intensity of light during seed production. Dadson and Noureldin (2001) reported that during soybean cultivation, soybean is exposed to many environmental factors that may encourage or retard development (vigour). Some factors are natural (such as light, darkness, and rain), while others are under the influence of man (planting date and cultural practices).

Significance differences ($p < 0.05$) were observed in dry root weight of plants from among the various districts. Plants obtained from Tolon district produced the highest root dry weight, while dry roots weight of plants from Savelugu and Yendi Municipality were the lowest. The differences could be attributed to variations in field conditions where seeds where obtained. Hampton (1995) reported similar results stating that variation in seed vigour both between and within seed lots is often considerable because seed vigour attributes may be affected by many sources. This source of variation results from environmental conditions during maturation (Carter and Hartwig, 1963).

5.2.4 Location (District) effects on vigour index for seeds obtained from different sources at nine weeks after sowing

The differences were observed in vigour index among plant from seeds obtained from the districts. Plants of seeds obtained from Yendi Muncipality having the highest vigour index whereas those plants from seeds acquired from Kumbungu district had the least. This could be attributed to variation in micro environmental and meteorological conditions at the time of seeds maturation. Yendi Municipality experienced the highest rain fall (147 mm) between Septembers to November in the production year 2015 while Kumbungu District had lower (135 mm) rainfall (Ghana Metrological Service 2015). The current findings have agreed with the work of Rienke and Joke, (2005) and Addo-Quaye et al. (1993) who report that two periods are critical for soybean moisture requirement; from sowing to germination and flowering to pod filling periods). Similarly, the differences observed in vigour index between plants of seeds from farmers' within communities in a particular district may also be due to variations in environmental conditions (soil nutrients and moisture as well as relative humidity) in the field where seeds were acquired. This agrees with the findings of Sun et al. (2007), who indicated that seed production environments are defined by the availability of soil nutrients, soil moisture and humidity during seed development and maturation. It is also reported that differences in micro-environment could be the possible cause of variation in seed viability which predisposed seeds to loss or decline in vigour. (Smicikla et al., 1992; Adam, McDonald Jr. and Henderlong, 1989). Seedling lengths along with germination percentage have significant and positive association with seed vigour (Egli et al., 1990; Egli and Tekrony, 1996; Joshi et al., 2009, Singh and Chauhan, 2010 and Rezapour et al., 2013)

5.3 Experiment 3: Laboratory work to determine the effects of farmers' practices on viability and vigour of soybean seeds

5.3.1 Seeds source (location) effects on laboratory germination % at ten days for seeds obtained from different districts

Significant differences ($p < 0.05$) were observed in germination percentage of seeds obtained from the various districts. The highest germination percentage of 79.7 % was recorded for seeds obtained from Yendi Municipality after ten (10) days of the experiment whereas seeds obtained from Tolon District had the lowest (66.2 %). Seeds from Tolon District which had the least germination in the field also recorded the least germination at the laboratory. The higher germination percentage recorded for seeds from Yendi Municipality may also be due to variation in environmental conditions as well as culture practices given to the mother plants during growth and also harvesting, processing and seeds source. For example, Yendi Municipality witnessed a higher rainfall of 147 mm during the period of seeds maturation (September to November) compared to Tolon District which recorded 119.8 mm rainfall during the same period (Ghana Metrological Service 2015). This assertion is in line with the work of Gokhale (2009), who reported that fluctuations in environmental conditions during seeds production are a factor affecting seed viability. Seed viability is affected by several 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). Differences among seeds from communities' in the same districts and seeds from farmers' in the same communities in the same district could further be due to variation in harvesting time and period of soybean. In early harvested seed crop, the seed quality (viability) will be very poor due to more number of immature and undeveloped seeds, while in delayed harvesting, seed quality (viability) are affected because of field weathering (Vasudevan et al., 2008). In the field germination, seeds obtained from Savelugu Municipality and Certified seeds recorded the highest germination percentages of 69.5 and 68.8 respectively. However, seeds obtained from Tolon District had the lowest germination percentage of 56.6. Comparing both field and laboratory germination test, germination percentages for seeds obtained from the various districts and certified seeds were below the standard germination test figure of above 85 % . This is worrying compared with the work of Dugje et al. (2009), who reported that germination test of seeds should be carried out prior to planting; the rate of germination should be above 85 % to obtain a good stand. The standard germination test, described in the Rules for Testing Seeds, the Association of Official Seed Analysts (AOSA, 1986), is the most widely accepted test for estimating seed viability internationally .Unfortunately, viability tests are inadequate predictors of field emergence for two reasons: 1) seldom are field conditions optimum as assumed by standard test conditions, and 2) seedlings are classified as either germinable or non-germinable after a seven-day period without regard to the progressive nature of seed deterioration (McDonald, 1980). Standard germination test according to Johnson and Wax (1978) and Vieira et al. (1991) shows non-significant correlation with field emergence under unfavorable environmental conditions. Green and Pinnell (1968) reported that field emergence and laboratory germination tests have low broad sense heritability estimates due to large environmental variances

5.3.2 Seeds sources (location) effects on vigour index at ten days of an experiment for seeds obtained from different districts

There were variations observed in vigour index among plants from seeds obtained from various districts. Plants from Yendi Municipality had the highest vigour index while those from Tolon district recorded least. The differences in vigour index might be due to variation in weather conditions of the sources of the seeds. Rainfall in Yendi Municipality from September to November of the production year in 2015 was 147 mm whereas Tolon district had 119.8 mm (Ghana Metrological Services 2015). The environment where seed develops can have great influence on viability as well as seed viguor (Sun et al., 2007). The finding of the present study is in agreement with Kandil et al. (2013) who as well reported differences in root and shoot length and root/shoot ratio in soybean in a similar experiment. The differences in vigour index of plants from seeds obtained from communities as well as farmers' may be attributed to distinctions in natural environmental condition of the locations of the community where seeds were produced as well as individual farmers practices at the time of seed production and development. The current finding may be supported by the fact that seed growth and development could be affected by environmental factors such as light, water and the type and amount of nutrients available (Pallais et al., 1987). Also seed quality is said to be affected by insufficient water during seed filling (Dornbos et al., 1989). Hampton, (1995) reported that, it is often significant for differences to occur in seed viability and vigour between and within seed lots, since many factors affects seeds quality attributes. The bases for these differences are the consequences of decisions made during planning of seed production and management or conditions of the environment for the period of growth and development (Carter and Hartwig, 1963).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

In this study, the following parameters: germination percentages, plant/shoot height, number of leaves, vigour index and seedling dry weights were evaluated. The main effects of source of seeds on soybean seeds viability and vigour were assessed for seeds collected from different districts in Northern Region of Ghana. There were significant differences among some of the parameters. In general, there were variations in viability and vigour between certified seeds and among seeds from different districts.

- Majority of soybeans farmers store their seeds in sacks placed on top of wooden material
- The study revealed that farmers perceive that storage methods may not have an effect on seeds viability and vigour
- Farmers indicated that seeds source has an effect on viability and vigour
- The results of the survey showed that soybean farmers in Northern Region stored seeds on their own for planting rather than patronizing certified seeds.
- Farmers indicated that diseases and pest are the most important production constraints in soybean production
- From experience, farmers indicated that soybean seeds stored for more than a year should not be used for production.
- From the experiments, sources influenced seeds viability

- Plant/shoot height from certified seeds were similar to those from farmers seed source from the districts.
- Certified seeds were more vigorous in terms leaf production than those from farmers' source seed from districts.
- Seeds obtained from certified seeds were more vigorous than those from farmers' seed source from the districts.
- Dry shoot and root weight of plants from seeds obtained from certified seeds were not different from dry shoot and root weight of plants from seed from farmers' seed source from the districts.

Recommendations

- From the study, the researcher recommends that farmers should patronize certified seeds rather than their own stored soybean seeds to enhance vigour in the field
- The researcher recommends that seeds source should be a key factor when obtaining soybean seeds from planting
- Further studies should be conducted into farmers' soybean seeds storage conditions as well as methods compared with standard storage for soybean
- The researcher also recommends that additional research could be carried out by comparing yield of certified seeds and farmers seeds

REFERENCES

Abba, E. J. and Lovato, A. (1999). Effect of seed storage temperature and relative humidity on maize (*Zea mays L.*) seed viability and vigour. *Seed Science and Technology*, (27): 101 -114.

Abbey, T. K., Ameyibor, K., Alhassan, A., Essiah, J. W., Fometu, E. and Wiredu, M. B. (2001). Integrated science for senior secondary schools. GAST. Ministry of Education.75-78.

Abdul-Baki, A. A. and Anderson, J. D. (1973). Vigor determination in soybean seed by multiple seed criteria. *Crop Science*, 13: 630 - 633.

Adam, N. M., McDonald Jr., M. B. and Henderlong, P. R. (1989). The influence of seed position, planting and harvesting dates on soybean seed quality. *Seed Science and Technology,* 17: 143 - 152.

Addo-Quaye, A. A., Saah, M. K., Tachie-Menson, C. K. B., Adam, I., Tetteh, J. P., Rockson- Akorly, V. K. and Kitson, J. E. (1993). General Agriculture for Senior Secondary Schools. Accra. Ministry of Education. 191-194.

Adebisi, M. A., Daniel, I. O. and Ajala, M. O. (2004). Storage life of soybean (*Glycine max Merr*.) seeds after seed dressing. *Journal of Tropical Agriculture*, 42: 3 - 7.

Adu-Dapaah, H. K., Asafo-Adjei, B., Owusu-Akyaw, M. and Amoah, S. (2004). Sustainable Soybean Production in Ghana. Paper presented at a Radio program on soybean in Ghana, 6 pages.

Aikins, H. M, Afuakwa, J. J. and Nkansah, E. O. (2011). Effect of different sowing depths on soybean growth and dry matter yield. *Agriculture and Biology Journal of North America*, 8: 2151-2517.

Al-Yahya, S. A. (2001). Effect of storage conditions on germination in wheat. *Journal* of *Agronomy Crop Science.* 186: 273 - 279.

Anfinrud, M. (1997). Planting hybrid seed production and seed quality evaluation. In: Sunflower technology and production, Schneiter, A. H. (Eds). Agronomy, Madison, Wisconsin, USA. 697 - 708.

Appleton, S. and Balituita, A. (1999). Education and agricultural productivity: Evidence from Uganda. *Journal of International Development*, 8(3): 415 - 444.

Arkansas Soybean Promotion Board (2011). Facts about Arkansas soybeans: Top 10 things you should know about Arkansas soybeans. Www.themiraclebean.com. Date accessed on 12th/12/17.

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. 1 - 39.

Ash, M. (2012). Soybeans and oil crops: Background. United Stated Department of Agriculture Economic Research Service. http://www.ers.usda.gov.

Association of Official Seed Analysts. (1986). Rules for testing seeds. Proceedings of *Association of Official Seed Analysts*, *6*: 1-126.

Association of Official Seed Analysts. ASOA (1983). *Seed vigour testing handbook.* AOSA No. 32.

Astegar, Z. R., Sedghi, M. and Khomari, S. (2011). Effects of accelerated aging on soybean seed germination indexes at laboratory conditions. *Notulae Scientia Biologicae, 3*(3): 126 - 129.

Awuku, K. A. (1991). Agricultural and environmental studies. Rebl. Evans Brothers Ltd, London. 334.

Bailey, J. E. (1974). Whole grain storage. In Christensen, C. M. (Ed.). Storage of cereal grains and their products. St. Paul, 333-360.

Balesevic-Tubic, S., Tactic, M., Dordevic, V., Nikolic, Z. and Dukic, V. (2010). Seed viability of oil crops depending on storage conditions. HELIA, 33: 153 - 160.

Balesevic-Tubic, S., Malenèiæ, D., Tatiæ, M. and Miladinovic, J. (2005). Influence of aging process on biochemical changes in sunflower seed. *HELIA*, *28*(42): 107 - 114.

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

Barton, L.V. (1943). Effect of moisture fluctuations on the viability of seeds in storage. Boyce Thompson Institute.13: 35 - 45.

Bartsch, J. A., Haugh, C. G., Athow, K. L. and Peart, R.M. (1979). Impact damage to soybean seed. Trans. ASABE, 29: 582 - 586.

Basra, S. M. A., Ahmad, N., Rehman, K. and Iqbal, N. (2002). Cotton seed invigouration by pre sowing seed humidification. *International of Journal Agriculture Biology*, 4:127 - 130.

Biabani, A., Boggs, L. C., Katozi, M. and Sabouri, H. (2011). Effects of seed deterioration and inoculation with *Mesorhizobium cicerion* yield and plant performance of chickpea. *Australian Journal of Crop Science, 5*(1): 66 - 70.

Bohnert, H., Nelson, D. E. and Jensen, R. G. (1995). Adaptation to environmental stresses. The Plant Cell, 7: 1099-1111.

Borget, M. (1992). Food Legumes: The Tropical Agriculturalist. *CTA*. 103 *Canola Oil" . Soyatech. Retrieved February 18, 2016. "Soluble Carbohydrates in Soybean". intechopen.com.*

Brooker, D .B., Bakker-Arkema, F. W. and Hall, C. W. (1992). Drying and storage of grains and oilseeds, Springer, New York, United States.

Burris, J. S., Edje, O. T. and Wahab, A. H. (1973). Effects of seed size on seedling performance in soybean: II. Seedling growth and photosynthesis and field performance. *Crop Science*, 13: 207 - 210.

Byrd, H. W. and Delouche, J. C. (1971). Deterioration of soybean seeds in storage. *Proceedings of Association of Official Seed Analysts*, 61: 41 - 57.

Caminiti, M., Casal, M., Maitiu, O. and Zeru, Y. (2007). Feasibility study of biofuel production in Ghana. Technoserve- Ghana report. 63pp.

Carter, J. L. and Hartwig, E. E. (1963). The management of soybeans. In: The Soybean: genetics, breeding, physiology, nutrition and management (Norman, A. G., ed). Academic Press, New York. 161- 226.

Casenave, E. C. and Toselli, M. E. (2007). Hydro priming as a pretreatment for cotton germination under thermal and water stress conditions. *Seed Science Technology,* 3: 88-98.

Coolbear, P. (1995). Mechanisms of seed deterioration. In: Basra, A. S. (Ed.). Seed quality: basic mechanisms and agricultural implications. Food Product Press, New York, pp. 223 -277.

Copeland, L. O. and McDonald, M. B. (2001). Principles of seed science and technology. 4th ed. Kluwer Academic Publishers. Norwell, Massachusetts.

Darryl, W., Dahl, J., Jacobs, L. and Laboski, C. (2004). Nutrient recommendation for field crops. Extention Bulletin E2904. Michigan State University. 32.

Delouche, J. C. (1968). Precepts of seed storage. Mississippi Short Course Proceed. pp 97-123.

Delouche, J. C. (1980). Environmental effects on seed development and quality. *Horticultural Science*, 15: 775 - 780.

Delouche, J. C. and Baskin, C. C. (1973). Accelerated aging techniques for predicting the relative storability of seed lots. *Seed Science Technology,* 1: 427 – 452.

Dornbos, D. L. (1995). Seed vigour. In: Basra, A. S. (Ed.). Seed quality: basic mechanisms and agricultural implications. Food Product Press, New York, 119 - 152.

Dornbos, D. L., Mullen, R. E. and Shibles, R. M. (1989) Drought stress effects during seed fill on soybean seed germination and vigour. *Crop Science,* 29: 476 – 480.

Dugje, I. Y. L. O., Omoigui, F., Ekeleme, R., Bandyopadhyay, P., Lava, K. and Kamara, A. Y. (2009). *Farmers' guide to soybean production in Northern Nigeria.* International institute of tropical agriculture, Ibadan, Nigeria. 21.

Dzogbefie, V. P., Arthur, P. L. and Zakpaa, H. D. (2007).Value addition of locally produced soybean in Ghana. *Journal of Science and Technology,* 27(2): 1- 9.

Earl, L. T. (2002). Stomatal and non-stomatal restrictions to carbon assimilation in soybean lines differing in water use efficiency. *Environmental and Experimental Botany*, 48: 237 - 246.

Ecoport. (2009). *Ecoport database*. Ecoport. http://www.ecoport.org/

Egli, D. B. and D. M. TeKrony. (1979). Relationship between soybean seed vigor and yield. *Agronomy Journal*. 71: 755 - 759.

Egli, D. B. and Tekrony, D. M. (1995). Soybean seed germination, vigor and field emergence. *Seed Science and Technology*, 23: 595 - 607.

Egli, D. B., Tekrony, D. M. and Spears, J. F. (2005). Effect of high temperature stress during different stages of seed development in soybean [*Glycine max (L.)* Merrill]. *Seed Technology*, 27: 177 - 188.

Egli, D. B., TeKrony, D. M. and Wiralaga, R. A. (1990). Effect of soybean seed vigor and size on seedling growth. *Seed Technology*, 14: 1 -12.

Ellis, R. H. (1992). Seed and seedling vigour in relation to crop growth and yield. Plant Growth Regulation, 11: 249 - 255.

Eskandari, H. (2012). Seed quality variation of crop plants during seed development and maturation. *International Journal of Agronomy and Plant Production,* 3(11), 557-560.

Evans, L. T. (1996). Crop evolution, adaptation and yield. Cambridge University Press. 500pp.

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

FAO. (2010). FAOSTAT. Food and Agriculture Organization of the United.

Finch-Savage, W. E. (1995).Influence of seed quality on crop establishment, growth and yield. In : Basra, S. (Ed.). Seed Quality. Basic mechanisms and agricultural implications. New York, USA: Haworth Press, 361±384.

Gary, L. K., and Dale, L. F. (1997). Growth and development of the soybean plant. Soybean production handbook. Kansas state university. 32pp.

Ghana Metrological Service (2015). Annual metrological summary report of 2015. Northern region, Tamale.

Gillman, D. F., Fehr, W. R. and Burris, J. S. (1973). Temperature effects on hypocotyl elongation of soybeans. *Crop Science*, 1(2): 246 – 249.

Gokhale, D. (2009). Post-harvest seed storage/handling. Syngenta foundation for sustainable agriculture. STAK Conference, Nairobi. 1 - 11.

Green, D. E and Pinnell, E. L. (1968). Inheritance of soybean seed quality I. Heritability of laboratory germination field emergence. *Crop Science*, 8(1): 5 – 11.

Guberac, V., Maric, S., Lalic, A., Drezner, G. and Zdunic, Z. (2003). Hermetically sealed storage of cereal seeds and its influence on vigour and germination. *Journal Agronomy Crop Science,* 189: 54 - 56.

Gupta, A. and Aneja, K. R. (2004). Seed deterioration in soybean varieties during storage-physiological attributes. *Seed Research, 32*: 26 – 32.

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

Hampton, J. G. (1995). Methods of viability and vigour testing: a critical appraisal. In: Seed quality: basic mechanisms and agricultural implications (Basra, A. S ed.). Food Products Press, New York. 81 -118.

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

Heatherly, L. G. and Elmore, R. W. (2004). Managing inputs for peak production in Soybeans: improvement production and uses. 3rd Ed. Madison Wisconsin, USA. 451 - 536.

Herbek, J. H. and Bitzer, M. J. (1988). Soybean production in Kentucky. Part III: Planting practices and double cropping. http://www.ca.uky.edu/afc/pubs/agr130/agr130.htm. Date accessed 20th /07/2017.

IITA, (2009). Soybean overview. Summary. 5. IITA Abadan.

ISTA (2011).International Rules for Seed Testing. International Seed Testing Association, Bassersdorf. 27- 40.

ISTA, (2005). International seed testing association international rules for seed.

ISTA, (2009). *Handbook of Vigour Test Methods.* 3rd Edn., International Seed Testing Association, Zurich, Switzerland.

ISTA. (2007). International rules for seed testing. International Seed Testing Association. *Journal of Science and Technology* (Ghana), 27 (2): 22 - 28.

Jafari, H., Najafi, R., Soltani, A. and Dastan, S. (2013). Seed deterioration and seedling germination of soybean (*Glycine max* L.) cv. Sahar. *International Journal of Agronomy and Plant Production.* 4: 3762 – 3766.

Johnson, R. R. and Wax, L. N. (1978). Relationship of soybean germination and vigor tests to field performance. *Agronomy Journal*, 70: 273 - 278.

Jones, H. G. and Jones, M. B. (1989). Some terminology and common mechanism: Plants under stress. New York: Cambridge University Press.

Joshi, S. C., Singh, N. I, and Chauhan, J. S. (2009). Soybean seed quality evaluation. *Nature and Science.* 7(5): 1545 - 0740

Justice, O. L. and Bass, L. N. (1978). Principle and practices of seed storage. Agricultural Handbook No 506. Washington, DC.

Kandil, A. A., Sharief, A. E. and Sheteiwy, M. S. (2013). Seedling parameters of soybean cultivars as influenced with seed storage periods, conditions and materials. *International Journal of Agriculture Science,* 5:330 - 338.

Keigley, P. J. and Mullen, R. E. (1986). Changes in soybean seed quality from high temperature during seed fill and maturation. *Crop Science*, 26: 1212 - 1216.

Khaliliaqdam, N., Soltani, A., Latifi, N. and Far, F. G. (2012). Quantitative response of soybean seed under controlled conditions. *American – Eurasian Journal Agriculture & Environmental Science*, 12(2): 224 - 230.

Khaliliaqdam, N., Soltani, A., Latifi, N. and Far, F. G. (2013). Laboratory tests for predicting emergence of soybean cultivars. *Plant Knowledge Journal*, 2(2): 85 – 93.

Khare, D., Raut, N. D., Rao, S. and Lakhani, J. P. (1995). Effect of seed size on germination and field emergence in soybean. *Seed Researcher*, 23(2): 75 – 79.

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 Journal Agricultural Research,* 34(4): 565 - 576.

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

Lacerda, A. D. S., Lazarini, E., Sá, M. E. and Filho, W. V. V. (2003). Storage of desiccated soybean seed and the evaluation of physiologic, biochemical and sanitary characteristics. *Brazilian Journal of Seeds,* 25: 97 - 105.

Lampe, J. W. (2009). Is equal the key to the efficacy of soy foods? *American Journal of Clinical Nutrition, 89*(5): 1664 - 1667.

Lawson, I. Y. D., Mensah, E. A. and Yeboah, E. N. (2008). Improving the establishment and yield of soybeans through planting depth and land preparation methods in northern Ghana *West African Journal of Applied Ecology,* 14, 11.

Liu, K. (1997). *Soybeans: chemistry, technology and utilization.* New York: Chapman & Hall. Ltd, London.

Lori, G. A., Sisterna, M. N., Rollan, M. C. and Barreyro, R. A. (2001). Effect of different damage factors on soybean seed quality. *Acta Agronomica Hungarica.* 49: 133 - 139.

Marco-Filho, J., McDonald, M. B., Tekrony D. M. and Zang, J. (1998). RAPD profiles from deteriorating soybean seeds. *Seed Technology*, 19: 33 - 44.

Marji, Mc-Cullough, ScD, R. D. (2012). *The Bottom Line on Soy and Breast Cancer Risk*. American Cancer Society. Retrieved August 2013.

Marshal, A. H. and Levis, D. N. (2004). Influence of seed storage conditions on seedling emergence, seedling growth and dry matter production of temperate forage grasses. *Journal of Seed Science Technology*, 32: 493 – 501.

Masuda, T. and Goldsmith, P. D. (2008). World soybean production, area harvested and long term projections. International food and agribusiness management review. 30.

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

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

McDonald, M. B. (1999). Seed deterioration: physiology, repair and assessment. *Seed Science Technology,* 27: 177 - 237.

McGee, D .C. (1995). Epidemiological approach to disease management through seed technology. *Annual Review of Phytopathology,* 33: 445 - 466.

Mercer-Quarshie, H. and Nsowah, G. F. (1975). Soybean in Ghana. In D. K. Whigham ed. Soybean production, protection and utilization. INSOY series. 6: 200 - 2007.

MoFA and CSIR (2005). Soybean production guide. Food crops development project. Ghana's Ministry of Food and Agriculture. 38pp.

MoFA, (2012). Strategy for soybean production and marketing in Kenya. Unpublished, 1-20.

Mpepereki, S., Javaheri, F. and Davis, P. (2000). Soybean and Sustainable Agriculture: Promiscuous Soybean in Southern Africa. *Field Crops Research,* 63: 137 – 149.

Naderidarbaghshahi, M. and Jalalizand, A. (2013). Correlation and simple regression modelsrelationship of some seed vigour tests and field seed emergence of crops. *International Journal of Plant Production* (1): 50 – 56.

Nagaraju, S. (2001). Influence of seed size and treatments on seed yield and seed quality of sunflower cv. Morden. M.Sc. Thesis, University of Agricultural Sciences, Dharwad, Karnataka, India.

Nakagawa, J. (1999). Testes de vigor baseados no desempenho de plântulas.Vigour desementes: conceitos e testes. Londrina: Abrates. 2, 1-21.

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 physico-chemical properties of soybean. Food Chemistry. 27 (1): 12 - 23.

Nastasija, M., Jelena, M. and Acimovic, R. (2008). Effect of nitrogen fertilizer application on growth and yield inoculate. Agrobot. *C/UJ, 36*(1), 48 51. Nations, Rome, Italy.

Nave, W. R. (1979). Soybean harvesting equipment: Recent innovations and current status. Proceedings of the World Soybean Research Conference 2, March 26-29, 1979, North Carolina State University, USA., pp: 433-449.

Ng, N. Q. (1988). Long-term seed conservation. In: Proceedings of International Conference on Crop Genetic Resources of Africa, Kenya. F. Attere, N. Ng and P. Perino (eds) pp 135–148

Ngeze, P. B. (1993). Learn how to grow soybean. Nairobi, Kenya: CTA Publ. 21pp.

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

Nobrega, L. H. P. and Vieira, R. D. (1995). Avaliação e classificação de cultivares de soja, quantoao comprimento do hipocótilo, sob condições de laboratório e casa e vegetação. Revista Brasileira de Sementes, Brasília.17 (2): 160 – 164.

Norman, M. J. T., Pearson, C. J. and Searle, P. G. E. (1995). Tropical food crops: in their Environment. 2nd ed. Cambridge, New York.

O'Hare, T. J., Bagshaw, W. and Johnson, L. G. (2001). Storage of oriental bunching onions. Post-harvest handling of fresh vegetables. In: Proc. of a workshop held in Beijing, China, 9-11 May of harvest maturity on soybean seed quality and Phomopsis sp. seed infection. *Crop Science,* 24: 189 - 193.

Osafo, D. M. (1997). Effect of population density on the soybean varieties in Ghana's forest zone. *Experimental Agriculture,* 13: 235 - 340.

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 Reseach*. 38 (1): 69 – 74.

Pallais, N., Villagarcia, S. Tapia, J. and Garcia, R. (1987). Effect of supplemental nitrogen on true potato seed weight. *American Potato Journal,* 64: 483 - 491.

Pandy, R. K., Herrera, W. A. T., Vellegas, A. N. and Pendleton, J. W. (1984). Drought response of grain legume under irrigation gradient: 111. Plant growth. *Agronomy Journal*, (76): 557 – 560.

Parde, S. R. Kausal, R. T., Jayas, D. S. and White, N .D. G. (2002). Mechanical damage to soybean seed during processing. *Journal* of *Stored Products Research*, 38: 385 - 394.

Passioura, J. B. (1997). Drought and drought tolerance: In: Belhassen, E. (Ed). *Drought tolerance in higher plants. Genetical, physiological and molecular biological analysis*. 1 – 6. Prentice-Hall Inc. Englewood Cliffs, New Jersey. 252 – 279.

Perry, D. A. (1 984). Factors influencing the establishment of cereal crops. *Aspects of Applied Biology,* 7: 65 - 83.

Perry, D. A. (1982). The influence of seed vigour on vegetable seedling establishment. *Scientific Horticulture,* 33: 67 – 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. 12 - 114.

Priestley, D. A., Cullinan V. I. and Wolfe, J. (1985). Differences in seed longevity at the species level. *Plant Cell* and *Environment*, 8: 557 - 562.

Prochazka, P., Stranc, P. and Stranc, J. (2013). Testing the vitality of seeds for the establishment of high-quality soy crop. Mendel Net. 141 - 146.

Rahman, M. M., Hossain, M. M., Anwar, M. P. and Juraimi, A. S. (2011). Plant density influence on yield and nutritional quality of soybean seed. *Asian Journal of Plant Sciences*, 10(2): 125 - 132.

Reuzeau, C. and Cavalie, G. (1995). Activities of free radical processing enzymes in dry sunflower seeds. New Phytol. 130: 59 – 66.

Rezapour, R., Arbat, K. H. and Yarnia, M. (2013). The effect of seed size on yield, harvest index and its correlation to soybean seed vigor. *Journal of Seed Science and Technology*, 3(2): 62 -75.

Richard, J. D., Greub, L. J. and Anlgren, H. L. (1984). Crop production, 5th edn. Prentice-Hall Inc. Englewood Cliffs, New Jersey. 252 – 279.

Rienke, N. and Joke, N. (2005). *Cultivation of soya and other legumes.* Agrodok- series No. 10. Agromisa. CTA publication. 69.

Saha, R. R. and Sultana, W. (2008). Influence of seed aging on growth and yield of soybean. *Bangladesh Journal of Botany*, 37 (1): 21- 26.

Santos, V. L. M., Silva, R. F. and Cardoso, A. A. (1987). Avaliação da qualidade de sementes de soja (*Glycine max* (L.) *Merrill*) colhidas em duas épocas, utilizando-se temperaturas sub esupra-ótimas. Revista Brasileira de Sementes 18(1): 56 – 57.

SARI (2012). *Soybean: A production guide for northern Ghana*. Alliance for a green revolution in Africa soil health project, 2009 SHP 005: 4 - 7.

Sarkodie -Addo, J., Adu - Dapaah, H. K., Ewusi-Mensah, N. and Asare, E. (2006).
Evaluation of medium maturing soybean lines for their nitrogen fixation potentials.
Journal of Science and Technology. 26 (2): 34 - 39.

Sheidaei, S., Abad, H. H. S., Hamidi, A., Mohammadi, G. N. and Moghaddam, A. (2014). Evaluation of soybean seed quality under long term storage. *International Journal of Biological. Science,* 5(3): 214 -219.

Shelar, V. R. (2008). Role of mechanical damage in deterioration of soybean seed quality during storage- a review. *Agricultural Reviews, 29*(3): 177 -184.

Shelar, V. R., Shaikh, R. S. and Nikam, A. S. (2008). Soybean seed quality during storage: A Review. *Agriculture Reviews,* 29 (2): 125 – 131.

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

Shrivastava, P. K. and Ojha, T. P. (1986). Features of material handling in case of soybean. Proceedings of the National Seminar on Soybean Processing and Utilization in India, November 22 - 23, 1986, CIAE, Bhopal, India.

Shurtleff, W. and Aoyagi, A. (2007). The soybean plant: Botany, nomenclature, taxonomy, domestication and dissemination. Soy information Center, California. 40.

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

Šimic B., Popovic, S. and Tucak, M. (2004). Influence of corn (*Zea mays* L.) inbred lines seed processing on their damage. *Plant, Soil and Environment* 50, 157-161.

Simic, B., Popoviæ, R., Sudaric, A., Rozman. V., Kalinovic, I. and Cosic. J. (2007). Influence of storage condition on seed oil content of maize, soybean and sunflower, *Agriculturae Conspectus Scientificus*, 72 (3): 211 - 213.

Singh, N. I, and Chauhan, J. S. (2010). Quality prediction of carry-over soybean. *Seed. Researcher*, 2(3): 66 - 69.

Sionit, N. and Kramer, P. J. (1977). Effect of water stress during different stages of growth of soybean. *Agronomy Journal,* 69: 274 - 278.

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

Smiciklas, K. D., Mullen, R. E., Carlson, R. E. and Knapp, A. D. (1 992). Soybean seed quality response to drought stress and pod position. *Agronomy Journal,* 84: 166 - 170.

Spears, J. F., Tekrony, D. M. and Egli. D. B. (1997). Temperature during seed filling and soybean seed germination and vigour. *Seed Science Technology,* 25: 233 - 244.

Statistics, Research and Information Directorate, SRID of Ministry of Food and Agriculture. (2012). Production Estimates. Accra, Ghana.

Sudheer, Kumar, M., Sridhar, R. B., Kiran, B. S., Bhilegaonkar, P. M., Shirwaikar, A. and Unnikrishnan, M., K. (2004). Anti-inflammatory and antiulcer activities of pahytic acid in Rats. *Indian Journal of Experimental Bioloigy (National Institute of Science Communication and Information Resources), 42*(2): 179 – 185.

Sun, Q., Wang, J. and Sun, B. (2007). Advances on seed vigour physiology and genetic mechanisms. *Agriculture Science,* China 6:1060 - 1066.

TeKrony, D. M. (1980). Environmental influences on soybean seed quality during production, p. 51-67. In Proceedings Fourth Annual Seed Technology. Conference Iowa St. University Ames, lA.

TeKrony, D. M. and Egli, D. B. (1977). Relationship between laboratory indices of soybean seed vigour and field emergence. *Crop Science*, 17: 573 - 577.

Tekrony, D. M. and Egli, D. B. (1997). Relationship between laboratory indices of soybean seed vigour and field emergence. *Crop Science*, 22: 682 - 683.

Tekrony, D. M., Egli, D. B. and White, G. M. (1987). Seed production and technology. In: Soybean: Improvement, Production and Use, Wilcox, J.R. (Ed.). 2nd Edn. American Society of Agronomy, Madison, WI., USA, ISBN-13: 9780891180906, 295 -353.

TeKrony, D. M., Egli, D. B. and Phillips, A. D. (1980). The effect of field weathering on the viability and vigor of soybean seed. *Agronomy Journal*, 72: 749-753.

Testing. (2005) Edition, International Seed Testing Association, Bassersdorf.

Troedson, R. J., Garside, A. L., Lawn, R. J., Byth, D. E. and Wilson, G. L. (1985). *Soybean in tropical and subtropical cropping systems.* Taiwan: AVRDC.

Tweneboah, C. K. (2000). Modern agriculture in the tropics. Co – Wood publishers. pp. 405

USDA. (2007). World soybean production. Soy stats. *American soybean association. Annual Report*. 2 pp.

USDA. (2011). *U.S. soybean inspection.* Available from http://www.usda.gov/oce/commodity/wasde/latest.pdf. Date accessed 17th/06/216.

USDA. (2016). *National Agricultural Statistics Service* (NASS), Agricultural Statistics Board, United States Department of Agriculture, 1949-1522 https://www.nass.usda.gov. Date accessed on 15th/05/2016.

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.

Vashisth, A. and Nagarajan, S. (2009). Germination characteristics of seeds of maize (*Zea mays L.*) exposed to magnetic fields under accelerated ageing condition. *Journal of Agricultural Physics*, 9: 50 - 58.

Vasudevan, S. N., Sudarshan, J. S., Kurdikeri, M. B. and Dharmatti, P. R. (2008). Influence of harvesting stages on seed yield and quality in fenugreek. *Karnataka Journal Agriculture Science*, 21 (1): 122 – 124.

Vieira, R. D., TeKrony, D. M. and Egli, D. B. (1991). Effect of drought stress on soybean seed germination and vigor. *Seed Technology,* 15: 12 - 21.

Vieira, R. D., Tekrony, D. M. Egli, D. B. and Rucker, M. (2001). Electrical conductivity of soybean seeds after storage in several environments. *Seed Science Technology,* 29: 599 -608.

Vucenik, I. and Shamsuddin, A. M. (2003). Cancer inhibition by inositol hexaphosphate (IP6) and inositol: From laboratory to Clinic. *The Journal of Nutrition (American Society for Nutrition), 133*(11): 3778S – 3784S.

Walters, C. Ballesteros, D. and Vertucci, V. A. (2010). Structural mechanics of seed deterioration: Standing the test of time. *Plant Science*, (179): 565 – 573.

Whigham, D. K. and Minor, H. C. (2003). Agronomic characteristics and environmental stress. In: Norman, A.G. (Ed.). Soybean physiology, agronomy and utilization. New York, 77 - 118.

Wier, S. (1999). .Effects of education on farmer productivity in rural Ethiopia. WPS-99. Centre for the Study of African Economics, University of Oxford, UK.

Yaklich, R. W. and Kulik, M. M. (1979). Evaluation of vigor tests in soybean seeds: Relationship of the standard germination test, seedling vigor classification, seedling length and tetrazolium staining to field performance. *Crop Science*, 19: 247 - 252.

Yoon, J. H. T., Lilian, U. J. and David, J. A. (1983). The effect of phytic acid on in vitro rate of starch digestibility and blood glucose response. *American Journal of Clinical Nutrition (American Society for Nutrition), 38*(6): 835 – 842.

World Health Organization (1994). Assessment of fracture risk and its application to screening for postmenopausal osteoporosis. Report of a WHO Study Group. Geneva. Technical Report Series, No. 843.

Ujjinaiah, U. S. and Sreedhara, M. V. (1998) .Effect of threshing methods on mechanical seed damage and quality of soybean seeds during storage. *Seed Technology News*, 28:34 - 35

Ng, N. Q. (1988). Long-term seed conservation. In: Proceedings of International Conference on Crop Genetic Resources of Africa, Kenya. F. Attere, N. Ng and P. Perino (eds) pp 135–148

Tekrony, D. M., D. B. Egli, J. Balles, L.Tomes, and R. E. Stuckey. (1984). Effect of date of harvest maturity on soybean seed quality and Phomopsissp. Seed infection. *Crop Science*, 24:189 - 193.

APPENDICES

Appendix 1: Questionnaire on Sources of Farmers' Soya Bean (*Glycine max* L.*)* Seed and Their Effects on Viability and Vigour in Northern Ghana

Research Survey Questionnaire
UNIVERSITY FOR DEVELOPMENT STUDIES
Faculty of Agriculture
Department of Horticulture

RESEARCH QUESTIONNAIRE
The purpose of this questionnaire is to collect information on soya bean seed source and storage in the Northern Region of Ghana. Information provided would be treated confidentially.

PART I
PERSONAL INFORMATION OF RESPONDENT
(1) Name of respondent (optional)
……………………………………………………………………………………………
(2) Community of respondent………………………………………………………………………………
(3) District……………………..Community……………………………………………….....
(4) House/Phone number………………………………………………………………………………..
……………………………………………………………………….................................
(6) Age of respondent/farmer
Less than 18 years ( )
18 – 35 years ( )
35 – 60 years ( )
Over 60 years ( )
(7)Is farmer head of the household: Yes ___ / No ___

If no, head of household is Male ___ / Female ___ and Age: ________________ years

(8) Total number of people in the household (i.e. people currently living in the homestead).

Age	No. of females	No. of males
0 – 16 years		
17 – 35 years		
35 – 60 years		
Over 60 years		

(9) What is the education level of the respondent, and the education level of the household head? **Specify the number of years** this education was attended.

(10) How much arable land do you have available for crop farming (incl. fallow land)?

Area: ______________ Unit: ______________

PART II
GENERAL INFORMATION OF SOYA BEAN IN THE REGION

(11) How long have you been cultivating soya bean?

<5 years ( ) 5-10 years ( ) >10 years ( )

(12)What was the size of your soya bean farm last season?

…………………………………………………………………………………………………

(13) Which variety of soya bean did you cultivate last season?
………………………………………………………………………………………………..
.………………………………………………………………………………………………
………………………………………………………………………………………………..

(14) Why this particular variety of soya bean?
………………………………………………………………………………………………..
.………………………………………………………………………………………………
……………………………………………………………………………………………......
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………………………………………………………………………………………………..
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……………………………………………………………………………………………….

(15) How long have you been cultivating the variety?
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..

(16) What proportion of your total soybean crop is used for home consumption and what proportion for sale? Tick what best describes your situation:

	Tick
1. All produce used for home consumption	
2. Most produce used for home consumption, small part used for sale	
3. Half of produce used for home consumption, half of produce used for sale	
4. Small part used for home consumption, most produce used for sale	
5. No produce used for home consumption, all produce used for sale	

(17) Importance of soya bean in the household

	Estimated proportion of total income (in %, make sure the total equals 100 %)
Crops other than soybean	
Soybean	
Livestock	
Casual labour in agriculture	
Casual labour off-farm	
Trade	

Other business	
Salaried job	
Pension	
Remittances	
Other________________________	

(18). for your soybean fields, how much do you harvest (per unit area of land) in a normal year?

Acreage..................................
Yield............................Units..

Challenges in soybean cultivation

(19) What challenge(s) do you have in soybean cultivation?

Tick which one is appropriate

1) Availability of seeds______2) Marketing of grain_____3) Poor germination of seeds____________

4) Pests and diseases________5) others (specify) __________

SEED SOURSES AND STORAGE OF SOYA BEAN
(20) Have you been storing soya bean seeds on your own for sowing?
Yes ( )
No ( )

(21) How do you store the seeds? Describe the storage method……..

If No, to QUESTION 20 from where did you get your seeds for planting during last season?
Friends/ Neighbors/ Relatives ( ) Agro input Dealers ( ) Local Market ( ) Research Institutions ( )

(21) Where do you intend getting seeds for planting this season? Friends/ Neighbors/ Relatives ( ) Agro input Dealers ( ) Local Market ( ) Research Institutions ( ), Own seeds ( )

(22) Do you test your seeds for germination, Viability or Vigour potential before they are sown?
Yes ( )
No ( )

(23) How do you test for germination?
Describe…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………………………………………………………………..

(24) If yes, what percentage of germination did you record in the previous year before sowing your seeds?
( ) Less than 40 %
( ) 40 -60 %
( ) 60 – 80 %
( ) 90 % and above

(25) If you do test germination of your seeds before sowing what is the minimum percent germination do you consider acceptable for you plant? If your germination falls below this level what do you do?..
....
....
(26) What do you think are the causes of poor germination in soybeans?...
....
(27) In your own view do you think the seed source or storage method(s) have an effect on the germination, viability and vigour of your soya bean seeds?

a. Seed Source

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

…………………………………………………………………………………………
…………………………………………………………………………………………

b. Seed Storage

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

Appendix 2 A: Seeds sources effects on plant height (cm) over time for seeds obtained from different districts at 3 WAS

District	Communities/Farmers																		District Mean
		f1	f2	f3	f4	Mean		f1	f2	f3	f4	Mean		f1	f2	f3	f4	Mean	
Kumbungu	Chayohi	22.0	20.2	19.4	19.4	20.3	Cheshegu	17.7	17.1	18.6	18.3	17.9	Kpaliga	18.4	18.9	17.9	20.2	18.9	19.0
Savelugu	Challam	18.8	20.2	20.4	20.6	20.0	Nyoglo	18.7	20.1	17.7	18.9	18.6	Young	22.9	20.5	19.6	19.1	20.5	19.9
Tolon	Gbulahigu	17.4	19.2	18.2	18.5	18.3	Tuunaayili	29.8	30.4	31.6	29.2	30.3	Yipelgu	24.7	25.2	24.0	21.6	23.8	24.1
Yendi	Kulpanga	22.8	25.9	27.4	20.7	21.2	Kushegu	24.5	22.6	24.1	21.4	23.2	Tusani	22.6	25.6	23.9	22.4	23.7	23.7
Certified Seeds	Seeds from Heritage	23.5	22.0	22.6	23.5	22.9	Seeds from R S I U	21.8	20.4	20.5	22.47	21.4	Seeds from U D S	23.4	22.9	23.4	21.5	22.8	22.4

District: L.S.D 1.010, P-Value, < .001

District*Community: L.S.D 1.750, P-Value, <.001

District*Community*Farmer: L.S.D 3.500, P-Value, 0.271

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4

Appendix 2 B: Seeds sources effects on plant height (cm) over time for seeds obtained from different district at 4 WAS

	Communities/Farmers																		
District		f1	f2	f3	f4	Mean		f1	f2	f3	f4	Mean		f1	f2	f3	f4		District Mean
Kumbungu	Chayohi	37.2	33.9	33.3	33.6	34.5	Cheshegu	29.8	31.2	29.7	31.9	30.7	Kpaliga	31.3	32.8	32.2	30.2	31.8	32.3
Savelugu	Challam	34.3	34.7	34.9	34.8	34.7	Nyoglo	33.9	36.3	34.4	35.2	34.7	Young	38.8	34.9	34.7	34.6	35.7	35.1
Tolon	Gbulahigu	29.7	33.3	31.4	32.5	34.7	Tuunaayili	44.2	45.1	50.9	47.5	46.9	Yipelgu	42.9	43.0	41.0	37.6	41.2	40.9
Yendi	Kulpanga	36.2	42.5	37.7	35.5	37.9	Kushegu	40.4	42.2	38.4	39.8	40.2	Tusani	41.4	42.7	40.7	40.1	41.3	39.8
Certified Seeds	Seeds from Heritage	42.6	38.9	40.5	39.1	40.3	Seeds from R S I U	39.2	36.8	37.1	39.3	38.1	Seeds from U D S	41.9	42.3	40.9	38.9	41.0	39.8

District: L.S.D 1.542, P-Value, < .001

District* Community: L.S.D 2.671, P-Value, <.001

District*Community*Farmer: L.S.D, 5.343, P-Value, 0.658

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4

Appendix 3 A: Seeds source effects on leaves number over time for seeds obtained from different districts at 3 WAS

District	Communities/Farmers																		District Mean
		f1	f2	f3	f4	Mean		f1	f2	f3	f4	Mean		f1	f2	f3	f4		
Kumbungu	Chayohi	30	30.8	28.4	32.4	30.4	Cheshegu	18.3	17.8	20.3	19.5	18.9	Kpaliga	17.4	20.7	18.1	21.1	19.3	22.9
Savelugu	Challam	23.3	26.7	26	26.7	25.7	Nyoglo	24.6	28.9	25.5	25.9	26.2	Young	28.2	26.5	21.9	24.5	25.3	25.7
Tolon	Gbulahigu	26.9	23.3	22.6	23.4	24.1	Tuunaayili	32.6	32.7	32.1	30.4	31.9	Yipelgu	33.5	34.8	33.3	31.2	33.1	29.7
Yendi	Kulpanga	21.2	21.8	21.6	20.9	21.4	Kushegu	22.6	22.6	24	25.3	24.3	Tusani	26.5	25.0	27.2	26.4	26.3	23.9
Certified Seeds	Seeds from Heritage	28.8	27.7	25.7	35.2	29.2	Seeds from R S I U	32.1	29	29.7	35.7	31.6	Seeds from U D S	30.9	30.5	28.4	29	29.7	30.2

District: L.S.D 1.895, P-Value, < .001

District* Community: L.S.D 3.283, P-Value, <.001

District*Community*Farmers': L.S.D, 6.566, P-Value, 0.918

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4

Appendix 3 B: Seeds source effects on leaves number over time for seeds obtained from different districts at 4 WAS

District	Communities/Farmers	f1	f2	f3	f4	Mean	Community	f1	f2	f3	f4	Mean	Community	f1	f2	f3	f4	Mean	District Mean
Kumbungu	Chayohi	41.2	42.8	40.4	44.4	42.2	Cheshegu	29.9	29.3	31.3	31.5	30.5	Kpaliga	29	32.7	30.1	32.0	30.9	34.5
Savelugu	Challam	35.3	38.7	37.3	38.7	37.5	Nyoglo	36.6	40.9	37.5	36.2	37.8	Young	40.2	38.5	33.9	36.5	37.3	37.5
Tolon	Gbulahigu	38.4	35.3	34.0	35.6	35.6	Tuunaayili	43.4	44.7	43.4	42.4	43.5	Yipelgu	45.5	46.8	45.3	42.6	45.0	41.4
Yendi	Kulpanga	32.2	32.7	33.6	32.9	32.9	Kushegu	37.2	34.1	36.0	37.3	36.2	Tusani	38.5	37.0	38.3	37.9	37.9	35.6
Certified Seeds (Control)	Seeds from Heritage	40.2	39.8	37.7	47.2	41.2	Seeds from R S I U	43.4	41	41.7	47.7	43.4	Seeds from U D S	42.9	42.5	40.4	41	41.7	42.1

District: L.S.D 1.921, P-Value, < .001

District* Community: L.S.D 3.328, P-Value, <.001

District*Community*Farmers': L.S.D 6.656, P-Value, 0.919

Where; f 1 means farmer 1, f 2 means farmer 2, f 3 means farmer 3, f 4 means farmer 4