EFFECT OF SEED SOURCE AND POST-HARVEST HANDLING TECHNIQUES ON SEED QUALITY AND YIELD OF SOYBEAN

OCHRAN KIPRUTO MUTAI

Bsc. Seed Science and Technology, University of Eldoret

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DECLARATION

This thesis is my original work and has not been presented for academic award of degree in any other university

Ochran Kipruto Mutai Signature………………………. Date………………..........

This thesis has been submitted for examination with our approval as University supervisors.

Prof. Rama D. Narla Signature………………………..Date……………………..…

Department of Plant Science and Crop Protection

University of Nairobi

Prof. James W. Muthomi Signature………………………..Date……………………….

Department of Plant Science and Crop Protection

University of Nairobi

Prof. Julius O. Ochuodho Signature…………………... …..Date………………………

Department of Seed Crop and Horticultural Sciences

University of Eldoret

DECLARATION OF ORIGINALITY

Name of Student …………………………………………………………………….

Registration Number …………………………………………………………………….

College …………………………………………………………………….

Faculty/ School/ Institute ……………………………………………………………………

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DEDICATION

To my dear mother Leah Tororei, my wife Bilha and baby Michal, my siblings Bilshan and Zadock, friends and classmates for their continued support, encouragement and prayers. God bless you all.

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro Ecological Zones
ANOVA	Analysis of Variance
AOSA	Association of Official Seed Analysts
ARDAP	Appropriate Rural Development Agriculture Programme
CIMMYT	International Maize and Wheat Improvement Centre
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistics
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ISTA	International Seed Testing Association
KALRO	Kenya Agricultural and Livestock Research Organization
MOA	Ministry of Agriculture
NICHE	Netherlands Initiative for Capacity Building in Higher Education
PDA	Potato Dextrose Agar
SPSS	Statistical Package for the Social Sciences

GENERAL ABSTRACT

Soybean (*Glycine max*) is a multipurpose crop which is utilized for food, livestock feed, industrial raw material and a source of bio-energy. However, its production is constrained by use of poor quality seeds from informal sources and inappropriate post-harvest handling techniques which lead to deterioration in seed quality. This study was carried out to determine the effect of seed source and post-harvest handling practices on soybean seed quality. A survey was conducted in Busia County in three agro-ecological zones (LM I, LM II and LM IV) using a questionnaire to obtain information on sources of seed, constraints and post-harvest handling practices of soybean. Seed samples were collected from sixty farmers, sixty local markets and one agro-dealer outlet and evaluated for analytical purity, seed coat damage, moisture content, germination percentage, fungal seed infection and seedling vigour in the laboratory. A sample from the farmers was used for seed multiplication to evaluate the effect of different threshing and drying methods on seed quality in terms of seed coat damage, germination, fungal seed infection, seedling vigour and crop yield. An experiment was also set up in the laboratory to evaluate the effect of different seed treatments and duration of storage on germination and seedling vigour of soybeans. From the survey, forty eight percent of the farmers used farm saved seeds, 23% and 29% obtained seeds from the local markets and community based organizations respectively. None of the farmers obtained seeds from the Agro-dealer outlets. Eighty percent of these farmers did not treat soybean seeds. Sixteen percent of the farmers reported poor germination and diseases to be the major constraints faced when using farm saved seeds while majority reported to not facing any challenge. The low soybean production could be attributed to the use of seeds from informal sources which have been associated with poor quality. Untreated seeds are not protected from infection by pathogens and may also be source of seed and seedling pathogens. Threshing with sticks was preferred by 92% of the farmers because it did not consume a lot of time while a few threshed with their hands and beating with sticks inside a sack. Seventy two percent reported three months storage period with about 10% storing for six months and beyond. Uncertified did not meet 98% analytical purity standard but attained over 75% germination standard. Farm saved and local market seeds had the highest percentage of seed coat damage, fungal seed infection and reduced seedling vigour compared to seed from agro-dealers. Hand threshed seeds had the highest percentage of analytical purity, percent germination, seedling vigour and least damaged seeds as compared to the other methods. This could be attributed to minimal damage on the seed coat. Oven dried seeds had minimal seed infection as the temperature used was high enough kill the pathogens but too high to damage the seed. Seeds treated with Monceren (Imidacloprid 233g/L + Pencycuron 50g/L + Thiram 107g/L) and Root guard (*Trichoderma spp., Bacillus spp., Pseudomonas spp., Aspergillus spp., Chaetomium spp., Esherchia spp. And Azorobacter spp*. 10g/5Kg of seed) gave the highest germination percentage of 90% while Apron star (Difeneconazole 200g/Kg + Metalaxyl 20g/Kg + Thiamethoxam 200g/Kg) gave the lowest germination percentage of 87.7%. This showed that contact fungicides were superior to systemic fungicides. One up to two months storage periods recorded higher germination percentage. Significant reduction in viability of seeds was observed on extension in duration of storage beyond three months due to depletion of seed's food reserves. Seed source and post-harvest handling practices significantly affected seed quality of soybean. Farmers therefore, should be advised and encouraged to adopt, hand threshing and oven drying techniques, seed treatment with contact fungicides and systemic insecticides and shorter storage periods as they improve germination and reduce seedling infections.

Key words: Soybean, post-harvest handling practices, seed treatment, seed quality

CHAPTER ONE

INTRODUCTION

1.1 Background

Soybean (*Glycine max*) is an important multipurpose crop utilized for food, livestock feed, industrial raw material and bio-energy (Myaka *et al*., 2005). It is also the world leading source of oil and protein (Fedaku *et al*., 2009) with 20% oil content, 40% protein and 35% of carbohydrates and is cholesterol free with low levels of saturated fatty acids. The biomass from soybean is an important source of animal feed, green manure and can also be used as mulch (Chianu *et al*., 2009). Consumption of low quantities of soybean protein daily lowers the risk of breast, colon and prostate cancers, heart diseases and good for people with lactose intolerance (Sirtor, 2001; Jakobsen *et al*., 2011). In Kenya soybean is being promoted as a cultural source of protein, cooking oil, income to farmers and for soil fertility improvement (Misiko *et al*., 2008). Sanginga *et al.,* (2003) estimated that soybean can fix 44-103 kg/ha of nitrogen reducing the need for expensive nitrogen fertilizers. It adds nitrogen to the soil enriching infertile soils and stimulating crops productions in rotation especially with cereals (Ojiem, 2006).

Although the global production of soybean has been on the rise, the estimated demand is about 300 million tones, which exceeds the current supply by over 40 million tons (FAOSTAT, 2010).In Kenya, soybean is grown in a wide range of ecological conditions ranging from the tropics to 52^{0}N. It can grow at 0-2000 meters above the sea level altitude under rainfall regimes of 900-2000mm per annum (Jaetzold and Schmidt, 1982). Despite its wide range of growing condition, production is generally low with production areas and yields remaining stagnant with little annual change since 1990. Western Kenya is the leading soybean production area in Kenya accounting for 80% of the total national soybean production with the main production areas being, Bungoma, Busia, Kakamega, Mt. Elgon, and Vihiga (Chianu *et al*., 2008). There is more production in Busia region as compared to other places. Kenya imports most of its soybean from Uganda (Tinsley, 2009).

Kenya consumes about 400,000 MT of vegetable oils with the local production of palm oil, sunflower and soybean oils only meeting a third of this demand (Chianu *et al*., 2008). In addition, other uses such as soybean cakes for animal feeds manufacturers, Kenya can easily absorb up to 10,000MT of soybean in raw form annually (Lokuruka, 2011). The annual consumption estimate of all soybean products range between 100,000 MT (Tinsley, 2009) to 150,000 MT (Hailu *et al.*, 2014) and annual production has never exceeded 5,000 MT (MoA, 2012) which brings a shortfall of over 95%. This deficit is filled through imports majorly from Uganda (Tinsley, 2009).

The gap is due to challenges facing soybean production in Kenya. FAOSTAT, (2016) data indicated soil fertility, lack of markets, unreliable rainfall, seed quality, pests and diseases as factors that constraint soybean production. This gap is further widened by the fact that majority of farmers plant seeds obtained from fellow farmers, open air market or own saved material from the previous harvest (Bishaw *et al*., 2012; Orr *et al*., 2014). In Ethiopia more than 95% of farmers obtain common bean seed from informal sources which include seeds saved by individual farmers, seed exchange among farmers and the local markets (Oshone *et al*., 2014). These seeds are usually of poor quality and may not be healthy. Seeds of such status either have poor germination or give rise to weak and infected seedlings which affect the final crop yield (Araujo *et al*., 2012).

In addition, soybean have fragile seed coat which is susceptible to physical damage and high oil content which make them to deteriorate faster compared to seeds of most crops (Priestley *et al*., 1985). The physical damage of soybean seed coat mainly occurs during post-harvest handling (Shelar, 2008). The embryo can be easily damaged since it lies just beneath the thin coat and bruises may also act as the entry points of pathogens which negatively affect germination, emergence and seedling establishment reducing crop stand and yield (Mertz *et al*., 2009). Therefore, the purpose of this study is therefore to evaluate the effect of the source, production practices and postharvest handling on the quality status of soybean seeds.

1.2 Statement of the problem

Poor quality, low availability of seeds and poor knowledge on post-harvest handling and seed quality are the major constraints affecting soybean production in many rural areas that have widened the gap between production and the demand. In the country, this gap has been further widened by most farmers using their own farm saved seeds, farmer to farmer exchange or buying from open air local markets to raise crops in the following season (Abuli, 2016). The quality of seeds obtained from these informal seed sources is not assured and such seeds may become important sources of pathogen inoculum which can spread and introduced to new fields (Karavina *et al*., 2008). The use of these poor quality seeds results in an average yield of 0.6 tons per hectare (MoA, 2012) which is much below the potential yields of 1.4 and 1.8 tons per hectare with the use of good quality seeds and under good farm management practices (Chianu *et al*., 2008). The situation is worsened by the fact that soybean seeds have a fragile seed coat and poor storability. Inappropriate processing and handling of these seeds may hasten deterioration and results to low germination, poor emergence, plant stand and yields. The cracks in the seed coat from improper practices may also act as entry points of microorganisms which cause seed decays and seedling diseases (Shelar *et al*., 2008).

1.3 Justification of the research

The demand for soybean in Kenya is high, ranging between 50,000 and 100,000 metric tons compared to annual local production which is less than 5,000 metric tons (MoA, 2012). The demand outstrips supply and the deficit is met through imports from other countries like Uganda, South Africa, and Nigeria which costs the country high revenue. This gap has been further widened by the fact that most of the farmers use seeds from one season to the next or use of seeds obtained from informal sources which are of unknown quality. This may lead to accumulation of seed-borne pathogen inoculum to levels that may lead to increased incidence of seed rots, seedling decays and abnormalities which eventually result to reduced yields (Oshone *et al*., 2014). To fill this gap there is need to improve local production of soybeans through the use of quality seeds and appropriate post-harvest handling practices.

The use of good quality seed therefore, is critical to increase food production (Adetumbi *et al*., 2011). In addition, availability and use of good quality seeds increase yields of soybeans (Sathish and Bhaskaran, 2013). Work on high yielding varieties and the use of systemic fungicides have been reported by most researchers (Bradley *et al*., 2008). However, work on the use different combinations of systemic and contact fungicides with systemic insecticides, botanicals have not been exploited maximally. Profiling for sources of seeds and appropriate post-harvest practices used by farmers in the rural areas has not been taken into consideration. Methods of handling also determine the extent of seed coat damage as reported by other researchers. Such damage result in physical impairment of essential seed structures (El-Abady *et al*., 2012) and the broken testa permit early entry and easy access of microorganisms making the seed vulnerable to fungal attack which reduces seed storage potential (Shelar, 2008) germination and vigour. The use of other techniques like oven drying, the use of biological and short storage durations have not been exploited well. The utilization of resources and techniques within the reach of the ordinary reduces the cost of production and adoption of these techniques improves the yield production.

Further, in Kenya's vision 2030 blue print, soybean has been identified as one of the crop which contributes to economic growth pillar and this will remain a dream if nothing much is done to improve soybean production to bridge the gap between the supply and the demand (MoA, 2012). To increase production, farmers need to access high quality seeds which have rapid emergence, growth and free of pests and diseases. Therefore determination of soybean quality status and the effect of post-harvest handling practices will provide useful information for appropriate handling of the sensitive crop seeds which will result to improved production.

1.4 Objectives

The broad objective of the study was to determine source of the seeds, quality status of soybean seeds used by farmers and the effect of post-harvest handling practices on seed quality of soybean.

The specific objectives of the study were:

i. To investigate sources of seeds, post-harvest handling techniques and quality status of soybean seeds used by smallholder farmers in Busia County.

ii. To evaluate the effect of different methods of threshing, drying, seed treatment and duration of storage on soybean seeds quality and yield.

1.5 Hypotheses

i. Clean seed sources and appropriate post-harvest practices increase the physical, physiological and health quality status of soybean by improving seed health, germination and vigour.

ii. Appropriate post-harvest handling techniques improve the physical, physiological and health status of soybeans by reducing disease incidence and seed coat damage.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of soybean

Soybean is a legume crop utilized as human food, livestock feed, source of bio-energy (Myaka *et al*, 2005) and important animal feed (Tinsley, 2009) because of its high protein and oil content (Maingi *et al*, 2006). Being an oil crop it has high oil content of 20% with low cholesterol levels making it the leading traded oil crop in the world (Chianu *et al*, 2008). Malema *et al*., (2006) also reported that it can be used as blender with other cereals flour like maize to better their nutritional value and improves the crust color and shelf life of baked goods. Further, Vandeplas *et al*., (2010) reported that soybean has been used as nutritional component in humanitarian aid to deal with masses stricken with hunger, malnutrition and those faced with a range of calamities like drought, floods and earthquakes. It also has an ability to fix nitrogen into the soil (Hartman *et al*, 2011).

Soy oil is also used in the manufacture of soaps, glycerin, printing inks, greases, lubricants, water proofing materials, oilcloth, linoleum, putty, resins, insecticides, disinfectants, antibiotics and adhesives (Endres, 2001).

2.2 Production of soybean

According to FAO, (2011) the three major soybean producers in order of importance are USA, Brazil and Argentina while the major consumers are USA, Canada, China and the European Union. In Africa, Nigeria is the highest producer with an average production of 486,000 tons under an area of 553,260 hectares, followed by South Africa with 205,270 tons from 122,870 hectares and Uganda with 155,500 tons from 139,500 hectares (FAO, 2010).

Soybean production in Kenya is estimated at 4,335 metric tonnes which correlates to 0.7% of the world production (FAO, 2011). The annual consumption estimate of all soybean products range between 100,000 MT (Tinsley, 2009) to 150,000 MT (Hailu *et al*., 2014) and annual production has never exceeded 5,000 MT (FAO, 2012) which brings a shortfall of over 95%. This deficit is filled through imports with Kenya importing majorly from Uganda (Tinsley, 2009). Kenya's annual demand for soybean as stated by Wasike *et al*., (2009) is above 100,000 MT which is the highest figure in the East African region. The national consumption according to data from Chianu *et al*. (2008) is divided between human consumption and livestock feed production with human consumption accounting for 10-15% of the total requirement.

The processing of soybean is dominated by national scale industrial processors (98-99%) which are BIDCO, Promisidor and Proctor and Allan. In Western region of Kenya, the annual soybean yield range between 200-560 kg/ha. However, it has been demonstrated that high yields of up to 1600 kg/ha can be obtained (Chianu *et al*., 2008). A survey carried out in 1998 in this region indicated that Nyala, Gazelle, and Duicker were the most widespread soybean varieties, most probably due to seed availability, rather than the choice of farmers (Kaara *et al.,* 1998). Between the years 2000 to 2011, soybean yields have been declining despite an expansion in the land area under cultivation (FAOSTAT, 2011).

2.3 Challenges in soybean production in Kenya

Many communities in sub-Saharan Africa depend majorly on agriculture. In this region, there is relatively slow expansion in area cultivated due to scarcity of arable land the rapid population growth (Sibiko, 2012). Most of the farmers in Kenya own less than two hectares of land (Altieri *et al*., 2012) and acreage under soybean has been declining significantly (FAO, 2013). Soybean production like common beans is hindered by erratic and poorly distributed rainfall, use of poor genetic materials, field and storage pests and declining soil fertility. Additionally, farmers are faced with challenges of access to certified seed, low household income from the crop and poor marketing system (Kavoi *et al*., 2016).

Agada, (2014) reported that majority of farmers were poor and do not have adequate financial resources to boost production. As a result they may not expand their production or adopt new profitable technology packages to boost productivity. These farmers are also faced with the high cost of farm inputs and are not able to produce maximally due to reduced resources which could increase production. The situation is also worsened by improper transport system which affects food availability and market prices. Most farmers were educated but had poor knowledge of improved production techniques which impede adoption and transfer of innovation. The findings further revealed that inefficient marketing arrangements exposed the farmers to exploitation by middlemen.

Neighboring farmers, own saved or local market outlets are the major sources that farmers explore to obtain seeds for the next season crop. The quality of seeds obtained from these informal sources is not assured and planting would result in poor germination, emergence, crop stand and low yields (Abuli, 2016).

Soybeans have a very thin seed coat which provides little protection to the embryo beneath it (Gagre *et al*., 2014). This makes soybeans susceptible to physical injury which may occur during post-harvest handling. Mishandling soybean seed therefore will lead to seed coat damage resulting to a reduction in its physiological quality (Shelar *et al*., 2008).

The dominance of other legumes like pigeon peas in semi-arid Eastern Kenya, beans in Western and Central Kenyan highlands, is due to the difficulty in cooking soybean seeds, high requirement of fuel and time required to prepare them as compared to other legumes (Oniang'o *et al*., 2003).

Low farm gate prices of soybean have greatly reduced its production. Soybeans fetch around Ksh. 50 per Kg. compared to Ksh. 80 per Kg. for common beans Tinsley (2009). For a farmer to make a profit, value addition is necessary as Vandeplas *et al*., (2010) reported that value added soybean fetches farm gate price of Ksh 150 per Kg.

Climate change is projected to increase temperature and precipitation variability in East Africa. Temperature in Africa has been projected to rise faster than the rest of the world which could exceed 4^0C by the end of 21^{st} century (Djanaguiraman *et al*., 2018). Climate change is expected to decrease yields by shortening growing season, amplifying water stress and increasing incidence of diseases, pests and weeds outbreaks (Niang *et al*., 2014). Among the grain crops, wheat is reported as the most affected with a projection of 72% yield loss. For other grain crops such as maize, rice and soybean up to 45% yield loss is expected (Adhikari *et al*., 2015). Schlenker and Roberts (2009) reported that increasing temperature up to 30^0C gradually increased yield of soybean but increasing the temperature beyond 30^0C resulted in sharp decline in yield. In addition, Lobell and Field (2007) reported 1.3% reduction in soybean yields per 1^0C increase in temperature. Grace *et al*., (2012) predicted that malnutrition state experienced in the country will get worse with change in climate and amplified droughts in the future.

Extension services play an important role in promotion of new technologies to the farmers and these services are usually provided by the ministry through their extension officers. However, the inadequate staff and resources within the ministry have constrained effective and efficient delivery of extension services to farmers which results to limited farmer access to extension services (Chemining'wa *et al.*, 2014). In addition, lack of motivation for the field officers could hamper their effectiveness (Agada, 2014).

2.4 Attributes of soybean seed quality

Quality seed is essential for optimum stand establishment and maximum yields in soybeans (Wekesa *et al*., 2015). Seeds of poor quality limit the potential yield and productivity of the farmer's labor. There are various parameters that are used to define seed quality. These include genetic, analytical purity, physiological, and pathological qualities

(Scott and Hampton, 1985). Soybean seed will be considered of poor quality status if the minimum standards of any of these quality parameters are not attained.

Genetic quality refers to a seed lot being true to type (ISTA, 2015). The seed lot is free of other crop seeds or other varieties that may give rise to off types. The seeds have uniform genetic make-up. A mixture of varieties can be a problem as they may mature at different times leading to problems during harvesting, post-harvest handling and results to poor yields. Each seed of an undesired variety in a mixture will produce seed when planted and those seeds will produce more seed so that each year the proportion of the undesired variety becomes greater. Field inspection followed by rouging during the growing period of the seed crop is one of the steps taken to insure varietal purity in certified seeds (Bishaw *et al*., 2012). Since soybean seeds are self-pollinated they have high genetic purity compared with cross pollinated crops.

Analytical purity is the uniformity of a selected seed lot in terms of seed size, free from physical damage, other seeds and absence of foreign or inert material. It is done to determine the percentage composition by weight of the sample being tested and by inference the composition of the seed lot. It further identifies the various species of seeds and inert material constituting the sample (ISTA, 2015; Scott, 1984). Production conditions, harvesting techniques and post-harvest handling methods influence the physical quality of a seed lot. Harvesting soybean before or after optimal maturity leads to increased physical damage on the seeds. The quality of a seed lot is considered superior if the percentage of pure seed is above 98% and the percentage other seeds and inert matter being as low as possible (Trivedi and Gunasekaran, 2013)

Physiological quality of seeds refers to intrinsic attributes of seeds which determine their capacity to germinate and emerge rapidly and to produce a uniform stand of vigorous plants under a wide range of field conditions that can be encountered during planting time (Delouche, 1973). It comprises of germination and vigour. Germination is the emergence and development of the seedling to a stage where the aspect of its essential structures indicate whether or not it is able to develop further into a satisfactory plant under favourable conditions in the field while vigour refers to the sum total properties of seed to give rise to a rapid, normal seedling under a wide range of environmental conditions (Marcos Filho, 2015).

A vigorous seed lot is the one that is able to germinate even in unfavorable environmental conditions (ISTA, 2015). Healthy seeds give rise to vigorous seeds with faster growth rate, making them to escape harsh conditions. Poor post-harvest storage and handling of soybean seeds lead seed quality loss through seed deterioration (Shelar *et al*., 2008). Long storage periods of soybean seed extending over three months in non-optimal storage conditions has been a major cause of loss of vigour and viability (Jaya *et al*., 2014). The difference in the ability to retain germination during storage may also be attributed to differences in seed vigour (Delouche and Baskin, 1973). This is caused by depletion of stored food reserves reducing the vigour and viability. Loss of viability is the last step in the long process of seed deterioration (Delouche, 2016). The decrease in seed vigour and other physiological changes happen before loss of germination and therefore seed with acceptable germination can be of low vigour.

Pathological quality also referred to as seed health is the presence or absence of disease causing organisms within a seed lot (ISTA, 2015) such as fungi, bacteria and viruses, nematodes and insects. Seed health is the most important seed quality parameter because most diseases initially in the seed may give rise to progressive disease development in the field reducing the commercial value of the crop and imported seed lots may also introduce diseases or pests into new regions. The use of proper seed production practices including seed treatment during seeds processing are among the major ways of managing pests and diseases (Sharma *et al*., 2014).

2.5 Factors affecting soybean seed quality

Characteristics that determine soybean quality include moisture content, foreign material, discoloration, breakage, heat damage, insect and fungal damage, and seed viability (Brooker *et al* 1992). In addition, variety, environmental conditions during grain formation, and post-harvest handling practices may influence these characteristic.

Soybean yielding is dependent on cultivar (Hintz *et al*., 1992) and can be improved through breeding (Cho and Scott, 2000). Productivity of any type of cultivar is also affected by the surrounding environment. Different environmental factors which affect seed formation and development include light, water, the kind and quantity of available nutrients. Drought stress during seed fill and pathological damage of seed has been shown to affect seed yield, viability and vigour (Chirchir *et al*., 2016). Seeds developed under moisture stress, nutrient deficiency and extreme temperatures often result in light, shriveled poor-vigour seed.

Seed coat damage whether induced by harvesting or conditioning equipment, as well as improper storage conditions is among the factors that adversely affect seed vigour (AOSA, 2009). Schaffer and Vanderlip (1999) found that soybean seed germination was reduced in seeds processed with moisture contents less than 10%. Moisture content determines the rate at which seeds deteriorate and has profound impact on storage longevity of seeds. Drying has been known to increase the longevity of soybean seeds (Ellis *et al.*, 1982) hence reducing seed moisture to the range of 4 to 7% essentially ensures retention of high germination for a year or more at ambient temperatures. The critical moisture content is the level below which further reduction in moisture content no longer increases seed longevity in hermetic storage (Rao *et al.,* 2006). Critical moisture content for soybean (*Glycine max*) has been found to be 3.3% (Ellis, 1998). When seeds are stored in equilibrium with a relative humidity of less than

68% no microbial growth will occur. Misra (1985) earlier reported soybean seed lots with low moisture content ranging between 12-14 percent suffer less physical damage and retained their viability. Seeds with moisture content less than 10% are prone to split while those with high moistures content may result in seed crushing and bruising which significantly reduce seed germination by accelerating deterioration (Van Utrecht *et al*., 2000).

Costa *et al*. (2001) found increased levels of breakage and seed coat rupture from mechanical harvesting. Soybean seed is prone to mechanical damage that occurs during post-harvest handling and processing which affect its viability and vigour during storage (Shelar, 2008). Khazaei and colleagues (2009) in their work reported that soybean seeds undergo severe pressure during threshing resulting to broken seeds, cracked seed coats and an irreversible internal injury. Saini *et al.*, (1982) reported that threshing techniques especially mechanical threshing affect seed quality reducing germination and vigour. Van Utrecht and colleagues (2000) also mentioned that since embryonic axis in soybean is placed near the testa it is very susceptible to bruising and impact injuries. Rahman and colleagues (2004) in their research observed that mechanical damage reduced seed vigour when soybean was harvested with 11-14% moisture content. Cain (1977) reported 11% moisture content to be the level with less mechanical damage in soybean. Seeds with damaged seed coat as a rule have less vigour and viability (Dubben and Filho, 2001).

Many fungal and bacterial pathogens of soybean negatively affect seed health and emergence (McGee, 1995). Phomopsis cause damage to seed coat and cotyledon tissues resulting in decline in germination and potential pre and post emergence damping off (Cochran, 2015). Bacillus seed decay caused by *B. subtillis* is a disease that is problematic in tropics and cause losses in the field and postharvest reducing germination when conditions are warm and moist (Sinclair, 1999b)

2.6 Seed treatment in the management of soybean diseases

Seed is a basic and vital input in agricultural productivity since over 90% of the food crops are grown from Seed (Keino *et al*., 2015) and the quality of the seed determines the yield. Seed-borne, soil-borne and early season diseases and insects have posed a great challenge which needs timely management (Sharma *et al*., 2014). Disease management practices like crop rotation, sanitation, mixed cropping sowing date adjustments (Sanjeev Kumar, 2012) to combat pathogens are no longer acceptable and are being reevaluated as a component of integrated pest management (Reddy, 2013). To deal with these limitations, a tool which brings a reasonable reduction of inoculum and ensures sustainable production and healthy ecosystem is seed treatment (Sanjeev Kumar, 2012). Seed treatment ranges from the simple dressing to film coating, priming and pelleting (Dubey, 2011; Sharma *et al*., 2014). It refers to exposure of seeds to physical, chemical or biological agents to provide protection against pests and diseases during germination, emergence and early growth stages of the plant (Forsberg *et al*., 2003). Seed treatment has improved over time from the use of simple techniques like soaking seeds in cypress and onions to modern, complex technologies of using fungicides and insecticides (FIS, 1999). Several methods of seed treatment which include physical, chemical and biological have since been adopted.

2.6.1 Chemical seed treatment

Chemical treatments are fungicides or insecticides which are applied to control seed and seedling diseases or insect pests. It is practiced worldwide due to its wide spectrum of controlling diseases and pests in the initial stages of crop development (Marcos Filho, 2015) however they can cause resistance to organisms, affect target and non-target organisms and contaminate the environment through leaching (Sharma *et al*., 2015). Zida *et al*., (2016) reported 25% increase in yields for sorghum seeds treated with binary pesticide. One of the active ingredients was Thiram (tetramethylthirum disulfide) a contact fungicide which belongs to dithiocarbamate group demonstrated to increase emergence and yield of sorghum (Girish *et al*., 2004). This type of fungicides have multisite activity hence control broad spectrum of diseases like stem gall of coriander, damping off, smut of millet and neck rot of onion (chao Yang *et al*., 2011). Biological agents like *Trichoderma* and *Bacillus subtilis* have been used to manage root rot diseases in rice and peas respectively. Fungicides like Thiram and carboxin have also been used to manage burnt and loose smut in wheat respectively (Sharma *et al*., 2015). Metalaxy can be used to manage *Pythium* and *Phytophthora*, Difenoconazole is used against *Alternaria*, *Ascochyta*, *Cercospora* and *Colletotrichum*, mefenoxam is effective against *Pythium*, *Phytophthora* and downy mildew. Metalaxyl works by inhibiting RNA synthesis by disrupting incorporation of uridine into RNA, Difenoconazole inhibits mitochondrial function by disrupting complex II of succinic dehydrogenase, fludioxonil impaires membrane bound transport processes by inhibiting the accumulation and incorporation of glucose and mannose into hyphal wall glucans, captan and PCNB (Mathre *et al*., 2001). Studies have shown that soybean plants are resilient and can tolerate early season damages without suffering economic loss (Gasper *et al*., 2015). Some of the chemicals used to control pest and diseases include Gaucho, Cruiser, Poncho, Apron Maxx, Trilex, Acceleron, and Allegiance/bean guard. Neonicotinoid seed treatments offer soybean plants a narrow window of protection of about three weeks after planting, (McCornack and Ragsdale, 2006). However, the residue remains in the soil for a long period of more than six months (Bonmatin *et al*., 2014). Dimethoate, Antracol and Dithane M45 have been reported to control pests and fungal diseases (Wekesa *et al*., 2015)

2.6.2 Seed treatment with physical methods

Physical method evolved after considering the side effects of chemicals on the ecosystem and organisms (Elwakil, 2003) and included hot water, dry heat and radiation treatments. Hot water treatment has been used to control many seed-borne diseases with temperatures hot enough to kill the pathogen and not the seed for example management of brassica canker, rice blast and pea blight (Floyd, 2005). Radioactive irradiation has been reported to be successful in a few case but not widely used because the exposure sufficient to control pathogens is enough to kill the seed (Bagegni *et al*, 1990). Other types like microwave treatment (Aladjadjiyan, 2010) have been used as seed treatment agent to manage microbial infestation however further research needs to be done on this type of treatment (Sharmar *et al*., 2014). Reddy *et al*., (1995) used microwave treatment successfully to disinfect seeds of mustards, wheat, soybean, peas and rice before sowing to eliminate microorganisms. The mechanism of these methods is killing the pathogens with high temperatures enough to just kill the microorganisms but retain the viability of the seed.

Wood ash has been found to be effective in seed preservation. Hayma (1990) reported ash as a dessicant suitable in storage of grain products in the tropical regions. Similarly, Oguntane and Adekunle (2010) in Nigeria on maize, melons and beans reported that wood ash of *Nauclea diderrichii* and *Piptadeniastrum africanum* proved to be effective in preserving the seeds, eliminating fungi and preventing weevil manifestation. In addition, Nyarko *et al*., (2006) found wood ash of *Afzelia africana* to be effective in maintaining viability of rosella seeds stored in plastic containers and polythene sacks as it had the highest germination percentage and vigour after one year of ambient storage in Ghana. Mazarin *et al*., (2016) in their studies found that ash from *Lorphira lanceolata* had detrimental effect on cowpea weevils (*Callosobruchus maculatus*). They further suggested that the ash had some toxic components that inhibited egg—laying and adult emergence causing mortality of the weevil. Akob and Ewete (2007) also reported that plant extracts have ovicidal, repellent, antifeedant and insecticidal activities against insect species resulting in storage pests. The mortality caused by wood ash could be attributed to stomach poisoning as the weevils feed directly on the grains (Adedire and Ajayi, 1996). In addition, as the insect crawl over the grains, the chemical components could lodge between the cuticular segments increasing water loss through abrasion of the cuticle (Mazarin *et al*., 2016). In addition ash contained silica, iron, calcium, phosphorus and nitrogen elements which could be responsible for insecticidal effect.

2.6.3 Biological seed treatment

Biological treatment involve treating seeds with beneficial microorganisms like fungi and bacteria for example *Trichoderma spp*, *Pseudomonas*, *Bacillus* and *Rhizobia* which ameliorate seed and seedling diseases (Mastouri *et al*., 2010) and promoting rapid and uniform seedling germination and plant growth (Moeinzadeh *et al*., 2010). Studies on various strains of *Pseuodomonas fluorescens* indicated improved plant growth (Raj *et al*., 2004). These strains inhabit plant roots and affect plant growth by mechanisms such as increased solubilization and uptake of nutrients or production of plant growth regulators (Kloepper *et al*., 1989).

Seed treatment has helped improve yields of many crops by ensuring uniform stand across wide range of soil types, cultural practices and environmental conditions (Shamar *et al*., 2014). It has been shown also to have beneficial effect on extending storage life of soybeans. Findings by Adebisi *et al*., (2004) confirmed that seed dressed with fungicides or insecticides showed extended shelf life than untreated seeds. In addition, it reduces the initial inoculum and enhances seed vigour which is critical to successful field emergence and crop establishment (Sharma *et al*., 2015). According to Bradley, (2008) fungicide treatment on soybeans prevented crop stand and yield losses under moist soil environment. Fungicides and insecticides have been found to guarantee protection of seeds and seedlings in the early stages of germination (Ludwig *et al*., 2011; Pereira *et al*., 2011). Further, seed treatment control disease, improve seed health, plant stand, germination and crop yield (Joshi *et al*., 2014). Kleczewski (2013) reported that fungicide treatment increased germination of poor quality if the low quality was because of fungal pathogen activity or unfavorable environmental conditions but not due to aged or physically damaged seeds. Presently, many farmers are neither familiar with the practice nor follow it as over 70% of them sow own saved seeds every season without any seed treatment (Sharma *et al*., 2015).

2.7 Post-harvest handling practices of soybean

Post-harvest management of soybean includes threshing, drying, cleaning and storage of soybean crop. The levels of management vary from one country to another depending on advancement of technology and the scale of production. Developed countries have mechanized most of their operations because of the technology and also the extensive hectares of land cultivated.

2.7.1 Different threshing techniques and their effect on seed quality

Threshing is a major operation carried out after harvesting to separate grains from soybean pods by striking. The methods of threshing vary widely from traditional methods in the developing countries to mechanized methods in the developed countries. The different techniques that have been explored include hand threshing, beating by sticks and machine threshing (El-abady *et al*., 2012). Soybean being a sensitive crop if not handled properly results in broken seeds, cracked seed coats and internal damage due to threshing pressure (Khazei *et al*., 2009). The percentage of grain damage is directly proportional to threshing method used (Miah *et al*., 1994). Mechanical threshing causes more damage to the bean compared to manual threshing (Saini *et al*., 1982). Hand threshing method has recorded higher germination percentage, least physical injury and higher vigour compared to beating on the floor (Reddy *et al*., 1995). Jha *et al*., (1995) threshed soybean seed by hand beating, machine threshing and tractor treading and stored them under ambient storage condition. They found that hand beating resulted in higher germination levels and reduced deterioration as compared to the other two methods. The physical damage caused during post-harvest handling influence germination ability and vigour of soybeans (Wilson and McDonald, 1992; Rahman *et al*., 2004; Spokas *et al*., 2008). Damaged seeds give rise to abnormal seedlings, have less resistance against pest and diseases and have minimum storage life (Salari *et al*., 2012).

2.7.2 Methods of seed drying

Drying is a phase of post-harvest system during which beans are rapidly dried to a safe moisture level to allow further processing or storage without further damage. The main reason for drying is to reduce moisture content and active respiration to limit exhaustion of nutrients reducing deterioration. High moisture levels encourage growth of harmful microorganisms and insects which cause seed deterioration (Malik and Jyoti, 2013). In addition, high moisture content in stored soybean encourages insect and microorganisms which brings about deterioration (Dugje *et al*., 2009). Drying process involve heated air going through the seed and absorbing humidity of the outermost layers of the seed reducing the moisture content in the beans. For 6-12 months storage soybeans should be dried to 13% moisture content levels and for even longer storage period the beans should be dried to moisture levels of between 10-11% (Dugje *et al*., 2009). Considerable losses have been reported to be incurred annually during storage because of inadequate drying (Srzednicki, 2012).There are two major methods of drying:

Natural drying consists of exposing the threshed beans to the sun for a period of two to four days. Beans are spread in thin layers on the drying surface and stirred frequently to encourage uniform drying. As a rule of thumb, for effective drying the relative humidity of the air must not exceed 70%.This kind of open-air drying is the most practical way to dry soybean, however, the beans can also be dried by putting them on a clean rack in a cold room or shade (Dugje *et al*., 2009). Seed with moisture content above 17% should be dried first under shade to bring moisture to levels below 17% then dried under intense sun. However, direct sunlight can also affect germination owing to high temperatures and ultraviolet radiations. Two to four days are needed to reduce the moisture content to 10-12%.

Artificial drying also known as mechanical drying involves exposing soybeans to a forced heated air in special equipment called dryers until drying is completed. The dryers consist of the body to hold the beans to be dried, hot air generator which heats the drying air and a ventilator which permits circulation of the drying air through the beans. Other techniques like solar, Freeze and oven drying have been used to dry food and vegetables apart from grains (Riadh *et al*, 2015).

2.7.3 Duration of storage and conditions on soybean quality

Storage condition and duration are important factors to be considered for maintenance seed quality during storage. Temperature, relative humidity, seed moisture content and microorganisms have been reported to be the major external factors that determine the degree of seed deterioration (Ghassemi-Golezani *et al*., 2010). Some seeds like soybeans, sunflower, peanuts and onions naturally have short shelf life (Malik and Jyoti, 2013) due to its high lipid content and polyunsaturated acids (Joshi *et al*., 2014). Seeds with high initial viability maintain their quality in storage longer than those with low viability. Cracked, broken and bruised seeds have been reported also to deteriorate more rapidly in storage than undamaged seeds. According to Shelar *et al*., (2008) high temperature combine with high seed moisture content hasten the rate of biochemical processes which trigger rapid deterioration. In addition, Seeds with high moisture content show increased respiration, heating and fungal invasion leading to a decline in seed viability and vigour. In such an environment of high humidity and high temperatures bacteria nd fungi thrive. These organisms induce seed deterioration by producing toxic substances which destroy the cells of the seed (Malik and Jyoti, 2013).

Long duration of storage reduces germination of soybeans (Joshi *et al*., 2014). Similarly, Yilmaz and Aksoy (2007) reported a gradual decline in germination percentage with an increase in duration of storage. Balesevic-Tubic *et al* (2010) reported that soybean germination declined more in conventional condition storage because of the variability in temperature and relative humidity as compared to seeds stored under controlled condition. The decrease in seed quality during storage can be attributed to ageing effect leading to depletion of food reserves, decline in synthetic activity of the embryo and death of the seeds due to fungal invasion (Gupta *et al*., 1993). According to Balasevic-Tubic *et al*., (2005) the auto oxidation of lipids and the increasing content of the fatty acids during storage are the main reasons for rapid deterioration in oil seeds. Malik and Jyoti (2013) revealed that deteriorated seeds had reduced germination percentage, vigour, emergence growth uniformity, yield impaired biosynthetic mechanisms, increased leachates and abnormal seedlings and fungal infection such as purple stain.

CHAPTER THREE

SOURCE, POST-HARVEST PRACTICES AND QUALITY OF SOYBEAN SEEDS USED BY FARMERS IN BUSIA COUNTY

3.1 Abstract

Majority of farmers growing legumes plant recycled seeds from informal sources for the next season crop. The quality of such seeds is unknown and usually ends in accumulation of pests, diseases and reduced yields. This study was carried out to determine production practices and quality of soybean seeds used by farmers in agro-ecological zones LM I, LM II and LM IV in Busia County. A purposeful survey was conducted with the help of a questionnaire to collect information on soybean production practices, source of seeds, and post-harvest handling practices. Seed samples were collected from sixty farmers, local market and one agro-dealers outlet. These seed samples were evaluated for analytical purity, seed coat damage, moisture content, germination percentage, fungal seed infection and seedling vigour. From the survey it was found that forty eight percent of farmers used farm saved seeds, 29% and 23% used seeds from community based organizations and local markets respectively. None of the farmers sourced certified seeds from agro-dealer outlets. This was due to high prices of certified seeds, insufficient availability of the seeds. Eighty percent of the farmers did not treat seed either before storage or before planting while the remaining 20% used different traditional ways like wood ash. Sixteen percent of the farmers reported poor germination and disease incidence as problems associated with using farm saved seeds. This may be attributed to unknown quality of soybean seeds the farmers obtained from these informal sources. Soybean rust (*Phakospora pachyrhizi*) was the most prevalent disease reported by 43% of farmers. Ninety two percent of farmers preferred to thresh soybean by beating with sticks and 81% sold their produce to the local markets and fellow farmers for general purpose. Sixty eight percent of farmers stored soybean for three months only. Seed from informal sources had low purity, higher seed coat damage and fungal seed infection as compared to certified seeds from the agro-dealers. The physical purity of seeds from the informal sector did not meet the ISTA minimum recommended standard of 98%, however their germination was comparable to 75% germination standard. Seeds obtained from the informal seed sources had reduced quality as compared to seeds from the formal sources. Farmers therefore, should be advised to adopt seed treatment or increase the use of certified seeds.

Keywords: Soybean, informal source, seed quality, seed production practices.

3.2 Introduction

In Africa, seeds used are supplied by formal and informal seed sector. According to Adetumbi *et al*., (2011) 100% of the seed dealers handle maize, 82% for cowpea and 82% vegetables compared to 27% for soybean seeds indicating that there is limited supply of soybean seeds compared to other grain crops and vegetables. This has led to about 70% of the farmers to recycle seeds from informal sources and because these seeds are of poor quality result in poor yields (Oshone *et al*., 2014).Financial constraints, lack of knowledge of seeding and high cost of certified seeds have also contributed to the use of own saved seeds (Clayton *et al*., 2009). In addition, lack of adequate and quality seed supply by the formal system and limited technical support to promote the informal seed system have hindered farmers from accessing improved quality seeds (Oshone *et al*., 2014).

In Kenya, soybean demand ranges between 100000 MT and 150000MT while production ranges between 1000MT and 5000MT. The deficit is usually filled through imports from other countries like South Africa and Uganda. This drains the revenue of the country. Western Kenya is the leading soybean production area in Kenya accounting for over 50% of the total national soybean production with the main production areas being Bungoma, Busia, Kakamega, Mt. Elgon and Vihiga (Chianu *et al*., 2008). According to Tinsley, (2009) larger percentages of imports come from Uganda. Busia town in Busia County is strategically positioned for trade between the two countries and large amounts of grain produce penetrate through with ease.

Soybean yield in this region still range between 200-560 kg/ha which is way below the demonstrated potential of1600 kg/ha (Chianu *et al*., 2008) due to challenges facing the farmers. In addition, Odendo *et al*., (2008) from their baseline survey revealed that communities in this region had interest in growing soybeans but had no access to improved varieties, unavailability of good quality seeds and have resorted to using seeds obtained from informal sources to raise crops in the following season. This study therefore aimed at investigating the source, post-harvest practices and quality of soybean seeds from the informal sources in Busia County.

3.3 Materials and Methods

3.3.1 Description of the study area

The study was carried out in Western Kenya, Busia County in three agro-ecological zones LM I, LM II and LM IV. The ecological conditions of this region are characterized by altitude range of between 0-2000 meters above the sea level, annual rainfall range of 900-2000mm with a mean temperature of 21.5^{0}C. The soils are mainly a complex of well drained, moderately deep to very deep, reddish brown to yellowish brown, friable clay orthric Ferralsols with dystric Nitosols. It experiences two rainy seasons with the long rains starting end of March to August and the short rains beginning in September to December. Agro-ecological zones LM I and LM II are also referred to as marginal sugarcane zones while LM IV is known as marginal cotton zone (Jaetzold and Schmidt, 1982). The ecological conditions of the zones are given in (table 3.1) below:

Table 3. 1: Characteristics of three Agro-Ecological zones in Busia County

Agro-Ecological Zones	Altitude in Meters	Annual mean temperature in ^{0}C	Annual average rainfall in mm	60% reliability of rainfall	
				1st rains	2nd rains
Lower Midland I	1300-1500	20.5-21.7	1800-2000	800-900	650-800
Lower Midland II	1200-1350	21.4-22.3	1550-1800	650-800	480-650
Lower Midland IV	1135-1200	22.3-22.7	900-1100	<400-480	<100-220

(Jaetzold and Schmidt, 1982)

3.3.2 Determination of soybean production practices and collection of seed samples

A survey was conducted in September 2016 at the start of the short rains season to document out seed source, production and post-harvest handling practices of soybean in

Busia County using a questionnaire. Three agro-ecological zones as mentioned in table 3.1 were considered for the study and targeting soybean farmers only in the region. A total of 20 farmers were interviewed per zone in the three zones using a semi structured questionnaire (Appendix I). Purposeful sampling method was used to select the farmers to be interviewed. This technique involved specific selection of farmers that grew soybeans. The sample size was determined using the formula below:

$$n = \frac{N}{(1 + N (e)^{2}}$$

Where n is the sample size, N is the population size. The assumptions of using the formula are, 95% confidence level, P= 0.05 and error limit (e) = 0.1 (Barrett *et al*., 2011).

Soybean seed samples of about 10,000seeds were collected from twenty farmers, twenty local markets from each zone of the three zones and one agro-dealer outlet sample from zone I in khaki bags and transported to Nairobi. There was only one agro-dealer dealing with certified soybean seeds in Busia Region. Laboratory experiments were then conducted at the Department of Plant Science and Crop Protection University of Nairobi. These seed samples were evaluated for their analytical purity, moisture content, seed coat damage, seed germination, fungal infection and seedling vigour.

3.3.3 Determination of physical purity of soybean seeds

Analytical purity of soybean seed was conducted in accordance to ISTA, (2015) guide lines. Each of the 10,000 seed samples were thoroughly mixed to obtain a homogeneous sample and four replicates of 1000 seeds sub-samples were drawn and analyzed on a whiteboard by separating the different components comprising the sample. The different components comprising the sample were grouped into, pure seed, inert matter, other crop seeds and weed seed. Pure seed refer to the species found to be predominant and intact in the test and include all botanical varieties and cultivars. Inert matter includes seed units and other foreign materials not defined as pure seed like broken seeds which are less than half the original size of seed. Other crop seeds are seeds of other crops different from the crop on test (ISTA, 2015). Percentage of each component was calculated as a fraction of the initial weight as indicated below:

$$\text{Percentage component (\%)} = \frac{\text{Weight of each component fraction}}{\text{Initial weight of the sample}} \times 100$$

3.3.4 Determination of moisture content and seed coat damage

Moisture content of the seed samples collected was determined using a moisture meter MT-16 by AgraTronix. Handful of soybean sub-samples were drawn from each of the collected samples and put to test. The test was repeated four times. The meter cup was filled with soybean seeds, closed and the readings recorded.

Seed coat damage was detected by sodium hypochlorite test as per Van Utrecht *et al*., (2000). Four replicates of 100 seeds were soaked in 1% sodium hypochlorite solution for 10 minutes. Seed were considered to be damaged when the seed coat appeared wrinkled, swollen or with loose coats. Damaged seeds were counted and the percentage estimate of seed coat damage calculated using the formula:

$$\text{Percentage seed coat damage (\%)} = \frac{\text{Number of damaged seeds}}{\text{Total number of seeds}} \times 100$$

3.3.5 Determination of germination percentage and germination rate

Germination test of the seed samples collected was done according to ISTA, (2015) guidelines on paper towel to determine the percentage of viable seeds in a sample. Seeds were surface sterilized in 2% sodium hypochlorite solution for five minutes to retard saprophytic fungal infestation followed by three changes of sterile distilled water. These were germinated in four replications of 100 seeds each in transparent plastic boxes lined with absorbent towel. Seed sample from the agro-dealer outlet was used as the control. These boxes were arranged in a completely randomized design (CRD) in the laboratory under room temperature conditions. The seed were routinely misted with sterile distilled water to prevent them from drying up. Germinated seeds were counted for fifteen days at an interval of five days starting on the first day of imbibition. Seeds were considered germinated when 2mm of the radicals protruded and germination percentage calculated as shown below (Chirchir *et al*., 2016).

$$\text{Germination percentage (\%)} = \left(\frac{\text{Number of germinated seeds}}{\text{Total number of seeds}}\right) \times 100$$

In addition, germination rate index which is an expression of the total number of seeds that germinate in a time interval was calculated by the formula:

$$\text{GRI} = \frac{\text{No. of germinated seeds at the time of first count}}{\text{Days of first count}} + \ldots + \frac{\text{No. of germinated seed at final count}}{\text{Days of final count}}$$

Seedlings were further grouped into normal seedling and abnormal seedling according to their appearance. The essential features used to identify and group the seedlings into the two categories were the primary and secondary roots, hypocotyl, epicotyl and mesocotyl, coleoptiles and the cotyledons. A seedling was considered normal if all the essential structures were intact, well developed and in proportion, or with slight defects and balanced development (ISTA 2015).

3.3.6 Determination of fungal seed infection

Soybean seeds were surface sterilized in 2% sodium hypochlorite for three minutes, followed by rinsing in three changes of sterile distilled water and blot dried on sterile paper towel. Four replications of 10 seeds per petri dish from each sample collected were plated on petri dish containing potato dextrose agar media and incubated for 3-7 days at 25^0c in alternating dark and light conditions (Alemu, 2014). Sodium chloride (13.4g/L) was added to the media to inhibit germination and 50ppm of streptomycin sulphate to inhibit bacterial growth. The number of seeds infected and the individual pathogen types were recorded and results expressed as a percentage. Fungi growing on PDA media plates were identified both visually and under the stereomicroscope by observing colony characters and morphology of sporulating fungi as Shovan *et al*., (2008).

3.3.7 Determination of seedling vigour

Germination was conducted in the laboratory as given in section 3.3.5 and left to proceed for fifteen days and on the fifteenth day seedling vigour was determined. Seedling vigour was determined by selecting 10 seedlings from each replicate of each of the samples and the root and shoot lengths taken using a ruler in centimeters. The mean seedling length and germination percentage were used to calculate the seedling vigour index an expression of the potential level of activity and performance of the seed during germination and seedling emergence using the formula by Abdul-baki and Anderson, (1973):

Seedling vigour index = Germination % x mean seedling length (Mean root length + Mean shoot length).

3.4. Data collection and analysis

Data on source of seed, varieties of soybean grown by farmers, constraints faced by farmers using seeds from informal sources, disease prevalence, cropping systems, threshing practices, grading and seed treatment and the duration of storage adopted by farmers was analyzed using IBM Statistical Package for Social Science (SPSS) version 20 by performing descriptive statistics. Data on analytical purity, seed coat damage, germination, fungal seed infection, seedling vigour and yield were subjected to analysis of variance (ANOVA) using GENSTAT 15th edition. Means were separated using Fischer's protected Least Significant Difference (LSD) was at 5% level of significance (Steel and Torrie, 1960).

3.5 Results

3.5.1 Seed sources and production practices used by soybean farmers in Busia County

From the survey it was found that smallholder farmers in Busia County used their own saved seeds from the previous season, local markets and community based organizations. Forty eight percent of the farmers used farm saved seeds, 29% and 23% used seeds from community based organizations and local markets respectively across the three zones. In agro-ecological zones LM I, local markets and community based organizations outlets shared an equal percentage of supplying seeds to farmers for planting. Farmers in agro-ecological zone LM IV sourced their seeds mainly from the community based groups. The highest percentage (65%) of farmers who used own saved seeds as compared to other zones was reported in agro-ecological zone LM II (Table 3.2).

Four major varieties of soybean, SB-19, SB-20 SB-25 and SC Squire were grown in Busia County. About 57% of the farmers reported to grow SB-19 and 28.3% of them grew both SB19 and SC Squire Varieties. SC Squire was the least preferred variety across the three zones and farmers preferred to plant it along SB-19. Farmers in agro-ecological zone LM II had a wide range of varieties to choose from as compared to agro-ecological zones LM I and LM IV. SB19 and squire were the most prevalent varieties in agro-ecological zone LM II while SB-19 dominated agro-ecological zones LM I and IV (Table 3.3). About 16% of the farmers reported diseases and poor germination as problems associated with using farm saved seeds (Table 3.4)

Table 3. 2: Percentage of farmers obtaining soybean seeds from different sources in three agro-ecological zones in Busia County

N=60	Agro-Ecological Zones			
Source of seed	LM I (%)	LM II (%)	LM IV (%)	Mean
Farm saved	40±8.3	65±8.3	40±8.3	48.3±7.6
Local market	30±4.4	25±4.4	15±4.4	23.3±7.6
Community based organizations	30±10.1	10±10.1	45±10.1	28.3±7.6

N=Sample size, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV, ± = is the standard error

Table 3. 3: Percentage of farmers growing different varieties of soybean in different agro-ecological zones in Busia County

N=60	Agro-Ecological Zones			
Varieties	LM I (%)	LM II (%)	LM IV (%)	Mean
SB-19	65±10.9	35±10.9	70±10.9	56.7±10.2
Squire	0±1.6	5±1.6	0±1.6	1.7±10.2
SB-19 and Squire	25±6.0	40±6.0	20±6.0	28.3±10.2
SB-20	5±3.3	15±3.3	5±3.3	8.3±10.2
SB-25	5±0.0	5±0.0	5±0.0	5.0±10.2

N=Sample size, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV, ± = is the standard error.

Table 3. 4: Percent farmers with different constraints with the use of farm saved seeds in Busia County

N=60	Agro-Ecological Zones			
Constraints of using farm saved seeds	LM I (%)	LM II (%)	LM IV (%)	Mean
Poor germination	5.0±5.2	17.5±5.2	0±5.2	7.5±25.4
Diseases	7.5±3.6	15.0±3.6	2.5±3.6	8.3±25.4
No constraint	87.5±8.8	67.5±8.8	97.5±8.8	84.2±25.4

N=Sample size, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV, ± = is the standard error

Basing on the symptoms described by the farmers, the most widely spread disease reported by was Soybean rust (*Phakospora pachyrhizi*) across the three zones. Over 50% of the farmers in agro-ecological zone LM II reported soybean rust incidence (Figure 3.1).

Across the three zones in Busia County, majority of the farmers planted soybean as a single crop. About 60% of the farmers in agro-ecological zones LM I and IV reported to plant soybean in pure stands while 50% in agro-ecological zone LM II reported to intercrop soybean with other crops (Figure 3.2).

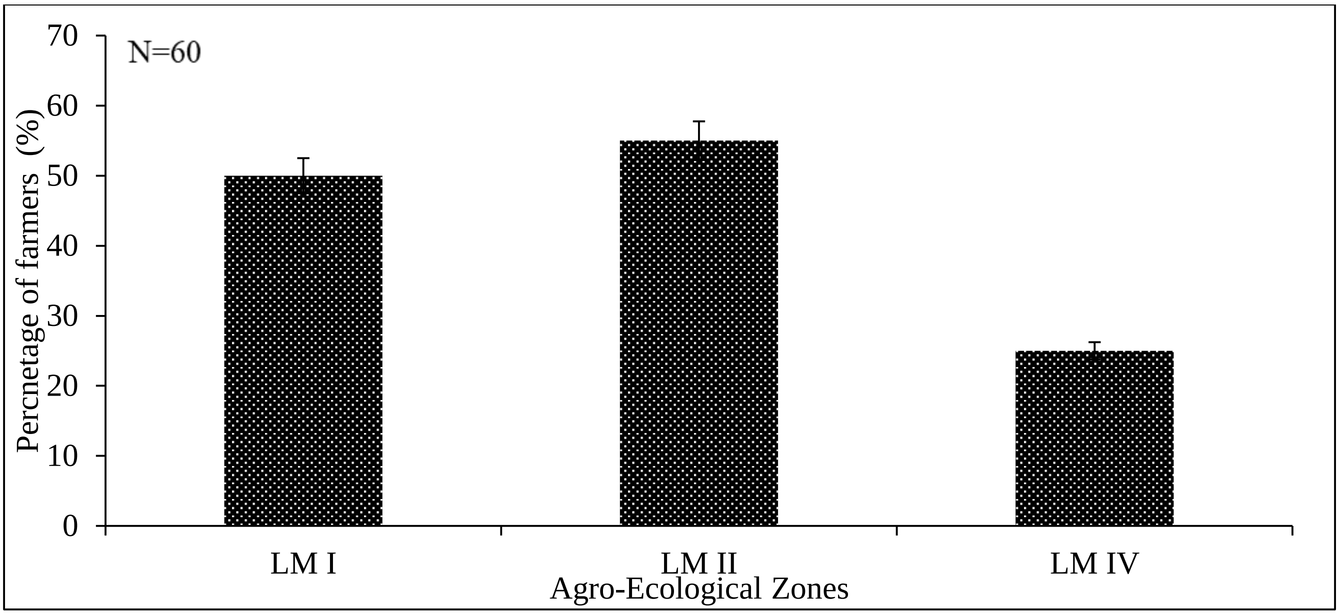

Figure 3. 1: Percentage of farmers who reported rust incidence in Busia County

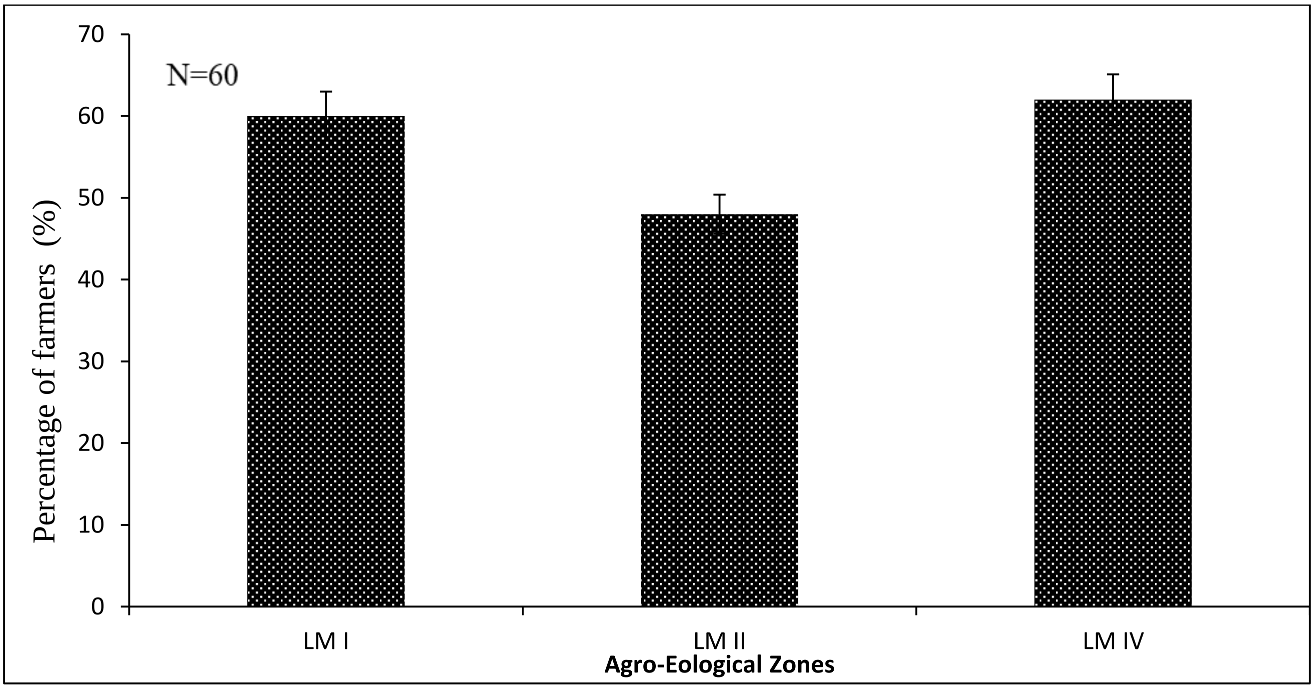

Figure 3. 2: Percentage of farmers growing soybean crop in pure stand in Busia County

3.5.2 Post-harvest handling practices adopted by soybean farmers in Busia County

About 92% of farmers threshed soybean crop by beating with sticks, 5% used their hands to remove seeds from the pods while 3% adopted sack method of threshing. All the farmers in agro-ecological zone LM I threshed soybean using sticks. Threshing inside the sack with sticks attracted only 5% of the farmers in agro-ecological zones LM II and IV. Hand threshing was practiced by 15% of the farmers in agro-ecological zone LM IV (Table 3.5).

Sixty five percent of farmers across the three zones graded soybean seeds before storage to select the best seeds (Figure 3.3). About 67% of the farmers in Busia County did not treat soybean seeds while 33% treated their seeds across the three zones. Around 60% of the farmers in agro-ecological zone LM I adopted seed treatment technology practice. In agro-ecological zones LM II and IV more than 70% of farmers did not treat the seeds either before storage or planting (Figure 3.3).

Table 3. 5: Percent farmers using different techniques to thresh soybean in three agro-ecological zones in Busia County

N=60	Agro-Ecological Zones			
Threshing method	LM I (%)	LM II (%)	LM IV (%)	Mean
Removing seeds from the pods by hand	0±5.0	0±5.0	15±5.0	5.0±29.2
Beating with stick on the floor	100±6.0	95±6.0	80±6.0	91.7±29.2
Beating pods inside a sack with sticks	0±1.7	5±1.7	5±1.7	3.3±29.2

N=Sample size, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV, ± = is the standard error

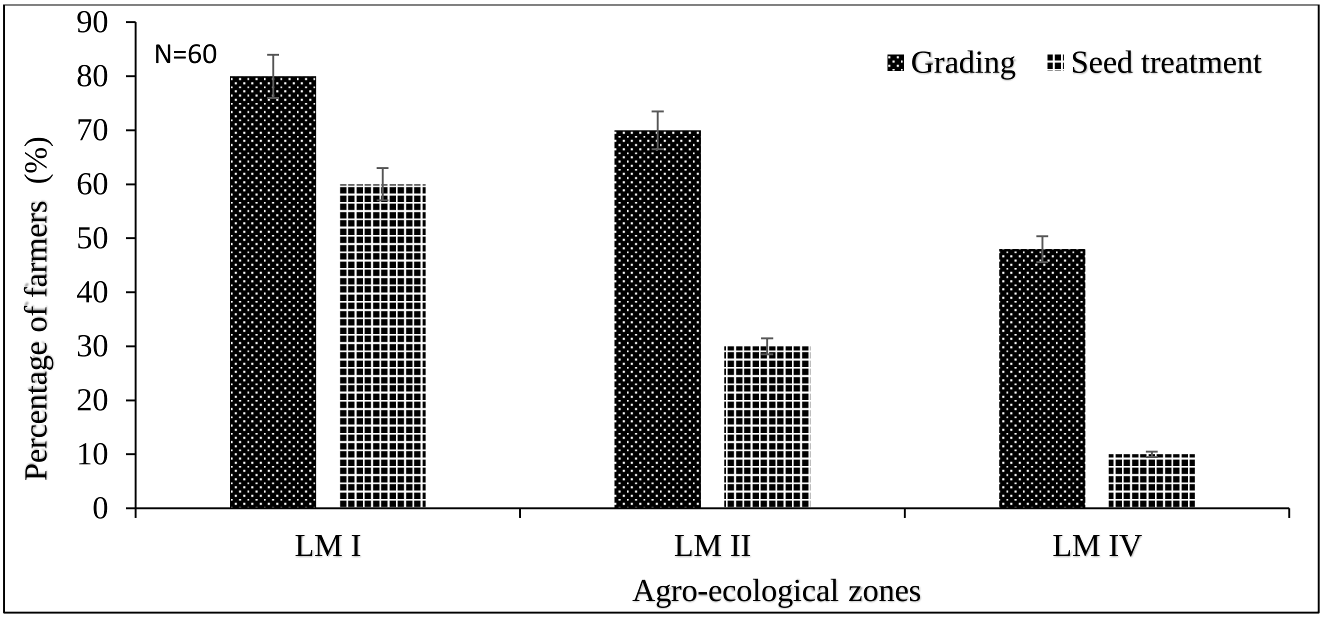

Figure 3. 3: Percentage of farmers grading and treating soybean seeds before storage in different agro ecological zones in Busia County

Farmers who treated soybean seeds employed different seed methods to protect their seeds from storage and soil pests. Only 8% of the farmers used Biofix inoculants to enhance nitrogen fixation before planting. Despite the new technologies, 10% of the farmers preferred the traditional methods of seed treatment before storage with 7% and 3% using wood and cow dung ash respectively across the three zones in Busia County. Farmers (20%) from LM II had adopted the new technology of treating seeds using inoculants while 10% continued to use old techniques of treating seeds with ash. Five percent of the farmers in LM I went out of the ordinary techniques and treated seeds with cement ash while 10% used cow dung ash before storage. However, none of the farmers in this zone used Biofix before planting despite getting extension services. Only 5% of farmers in LM IV used ash and Biofix with majority not applying any seed treatments (Table 3.6).

Farmers across the three zones in Busia County reported to receive extension services from the government and non-governmental organizations (Figure 3.4).

Table 3. 6: Different methods of seeds treatment used by farmers (%) in three agro-ecological zones in Busia County

N=60	Agro-Ecological Zones			
Seed treatments	LM I (%)	LM II (%)	LM IV (%)	Mean
Cow dung ash	10±3.3	0±3.3	0±3.3	3.3±15.0
Ash	5±1.7	10±1.7	5±1.7	6.7±15.0
Cement dust	5±1.7	0±1.7	0±1.7	1.7±15.0
Biofix	0±6.0	20±6.0	5±6.0	8.3±15.0
No treatment	80±5.8	70±5.8	90±5.8	80.0±15.0

N=Sample size, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV, ± = is the standard error

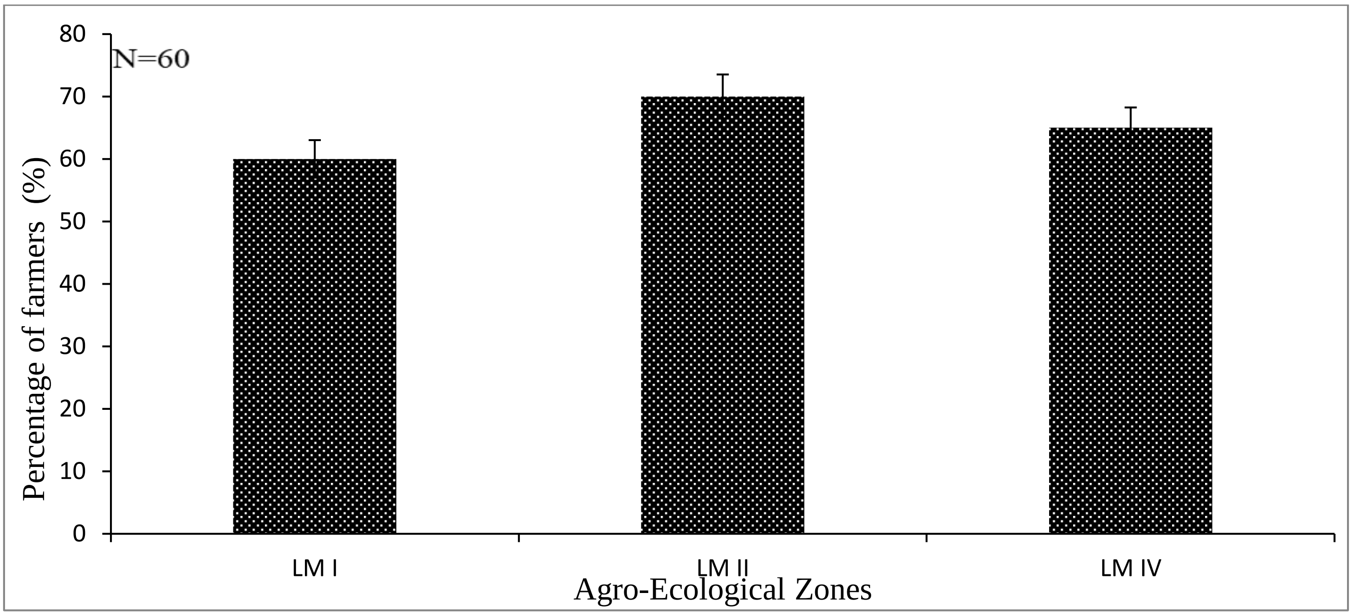

Figure 3. 4: Percentage of farmers who received extension services in Busia County

Farmers stored soybean seed up to a period of twelve months. However, majority (68%) reported to have stored seeds for three months. Only 5% as the smallest group stored their seeds for one year. Around 8% stored for one month, 7% stored for two months and about 12% of farmers stored for six months which was equivalent to two growing season. Farmers stored seeds for only two to six months period in agro-ecological zone LM II. While in agro-ecological zone LM IV seeds were stored for twelve months (Table 3.7)

Table 3. 7: Percentage farmers with different storage periods of soybean seeds in three agro-ecological zones in Busia County

N=60	Agro-Ecological Zones			
Duration of storage	LM I (%)	LM II (%)	LM IV (%)	Mean
Up to 1 month	10±4.4	0±4.4	15±4.4	8.3±12.1
1 to 2 months	5±1.7	10±1.7	5±1.7	6.7±12.1
2 to 3 months	75±9.3	80±9.3	50±9.3	68.3±12.1
3 to 6 months	10±1.7	10±1.7	15±1.7	11.7±12.1
Over 12 months	0±5.0	0±5.0	15±5.0	5.0±12.1

N=Sample size, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV, ± = is the standard error

3.5.3 Effect of seed source on analytical purity of soybeans

The analytical purity components of the seed samples from different sources differed significantly. Across the agro-ecological zones there was no significant difference in analytical purity of seeds from the three sources. Seeds obtained from agro-dealers had the highest percentage of pure seed meeting the 98% minimum analytical purity standard as compared to seeds sourced from the farmers and local markets. Seed samples from farmers and local market outlets were contaminated with other crop seeds and foreign materials while those from agro-dealer had less contamination (Table 3.8).

Table 3. 8: Analytical purity of soybean seed samples from various sources in three zones in Busia County

Source	AEZ	Components		
		Pure seed	Other crop seed	Inert matter
Agro-dealer	Control	99.8a	0.1a	0.1a
	Mean	99.8	0.1	0.1
Farm-saved	LM I	93.0a	1.4a	5.7c
	LM II	91.2a	0.2b	8.5a
	LM IV	93.2a	0.5b	6.3b
	Mean	92.5	0.7	6.8
Local market	LM I	91.4a	2.3a	6.3b
	LM II	91.5a	1.5b	7.0a
	LM IV	91.5a	1.8b	6.7b
	Mean	91.5	1.8	6.7
	Overall Mean	94.6	0.9	4.5
	LSD ($P \leq 0.05$) Source	1.0	0.5	0.7
	LSD ($P \leq 0.05$) AEZ	1.0	0.5	0.7
	LSD ($P \leq 0.05$) Source x AEZ	1.8	0.9	1.1

LSD=least significance difference, CV=coefficient of variation, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV

3.5.4 Effect of seed source on moisture content, seed coat and insect damage of soybean seeds

The data collected indicated that seeds from the informal sources had 88% damaged seed coats as compared to seed from agro-dealer (82%). Moisture content of the seed from the three sources did not differ significantly. Seeds collected from the informal outlets had similar results on damage caused by insects. Farm saved seeds from LM II had the highest insect damage across the zones while those from LM IV had the highest level of seed coat damage. Similar observations on seed coat damage were made on seeds obtained from the market. Seeds from the local market from LM IV showed higher levels of insect damage by insect but did not significance differ from LM I and LM II (Table 3.9)

Table 3. 9: Percent moisture content, seed coat damage and insect damage of soybean seed samples collected from different sources in the three agro-ecological zones in Busia County

Source	AEZ	Moisture content (%)	Seed coat damage (%)	Insect damage (%)
Agro-dealer	Control	9.1a	81.8a	0.5a
	Mean	9.1	81.8	0.5
Farm-saved	LM I	9.5a	81.7c	1.7a
	LM II	9.1b	89.9b	1.9a
	LM IV	8.5c	93.7a	1.2b
	Mean	9.1	88.4	1.6
Local market	LM I	9.5a	80.5c	1.6a
	LM II	9.1b	89.6b	1.5a
	LM IV	9.1b	93.1a	1.7a
	Mean	9.2	87.7	1.6
	Overall Mean	9.1	86.0	1.2
	LSD ($P\leq0.05$) Source	0.2	1.8	0.3
	LSD ($P\leq0.05$) AEZ	0.2	1.8	0.3
	LSD ($P\leq0.05$)Source x AEZ	0.3	3.0	0.5

LSD=least significance difference, CV=coefficient of variation, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV

3.5.5 Effect of seed source on germination and seedling vigour of soybeans

Germination percentage of soybean seeds from different sources in the three agro-ecological zones differed significantly. Germination percentage of the seeds across the zones and the sources of seed met the minimum germination standard recommended for soybean seeds of 75%. Agro-dealer seeds recorded the highest germination percentage of 90% followed by local market (76%) and farm saved seeds (75%). High germination rate, number of normal seedlings and seedling vigour index was also observed on seeds from this source. Seed sourced from farmers and local markets seeds in LM I recorded had the highest germination percentage, germination rate and vigour as compared to seed from LM II and IV.

In comparing germination across sources and zones, seeds obtained from farmers in zone I attained the highest germination than even the ones from formal sources (Table 3.10).

Table 3.10: Percent germination and seedling vigour of soybean seed samples from different sources in three agro-ecological zones in Busia County

Source	AEZ	Germination%	Normal seedling	Seedling Length (cm)	Seedling vigour index
Agro-dealer	Control	90.0a	82.5a	8.4a	7.6a
	Mean	90.0	82.5	8.4	7.6
Farm-saved	LM I	91.1a	80.5a	8.5a	7.9a
	LM II	72.9b	67.1b	5.7b	4.7b
	LM IV	61.7c	59.6b	2.4c	1.7c
	Mean	75.2	69.0	5.5	4.8
Local-market	LM I	89.9a	76.9a	8.3a	7.7a
	LM II	82.5a	72.6a	6.5b	5.8b
	LM IV	55.4b	50.0c	5.4b	3.7c
	Mean	75.9	66.5	6.8	5.7
	Overall Mean	80.4	72.7	6.9	6.0
	LSD ($P \leq 0.05$)Source	4.4	4.4	0.8	0.8
	LSD ($P \leq 0.05$)AEZ	4.4	4.4	0.8	0.8
	LSD ($P \leq 0.05$)Source x AEZ	7.7	7.6	1.4	1.4

LSD=least significance difference, CV=coefficient of variation, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV

3.5.6 Effect of seed source on fungal seed infection of soybeans

Infection of seeds collected from different sources and zones differed significantly. High fungal seed infection was observed on seeds from the informal sources. Seeds collected from the agro-dealer had the least incidence of fungal seed infection with only *Peniciliium spp*. being the only fungal infection observed. Seeds that were collected from farmers and market in LM I had high number of seed infection. The findings indicated high incidence of *Cercospora kikuchii* on seeds collected from the market in LM I while *Aspergillus flavus* infected seeds of most farmers in LM I (Table 3.11).

Table 3. 11: Percentage of fungi in soybean seed samples from various sources in different agro-ecological zones in Busia County

		Fungi (%)				
Source	AEZ	Infected	*C. kikuchii*	*A. flavus*	*A. niger*	*Penicillium spp.*
Agro-dealer	Control	10.0a	0.0a	0.0a	0.0a	10.0a
	Mean	10.0	0.0	0.0	0.0	10.0
Farm-saved	LM I	50.0a	1.0a	19.5a	12.0a	17.5a
	LM II	15.7b	0.8a	1.0b	1.0b	13.0a
	LM IV	20.0b	1.5a	3.0b	2.5b	13.0a
	Mean	28.6	1.1	7.8	5.2	14.5
Local market	LM I	30.5a	4.5a	3.5a	4.5a	18.0a
	LM II	17.5b	2.0b	6.0a	1.0a	8.5b
	LM IV	21.5ab	0.0b	2.0a	1.0a	18.5a
	Mean	23.2	2.2	3.8	2.2	15.0
	Overall Mean	20.6	1.1	3.9	2.4	13.2
	LSD ($P \leq 0.05$)Source	5.5	1.3	2.7	2.1	4.4
	LSD ($P \leq 0.05$) AEZ	5.5	1.3	2.7	2.1	4.4
	LSD ($P \leq 0.05$)Source x AEZ	9.4	2.2	4.7	3.6	7.7

LSD=least significance difference, C-Cercospora, A-Aspergillus, spp.-species, LM I= Lower Midland Zone I, LM II= Lower Midland Zone II, LM IV = Lower Midland Zone IV

3.6 Discussion

3.6.1 Seed source and production practices adopted by soybean farmers in Busia County

Most of the farmers in Busia County utilized soybean seeds from the informal sources with majority of them using farm saved seeds usually obtained from the previous season. The formal seed source supplied inadequate seed, as reported by Adetumbi *et al*.,(2011) that 100% of the seed dealers handled maize, 82% for cowpea and 82% vegetables seeds compared to 27% for soybean seeds hence limited supply. This has made farmers to use the readily available seed material to raise crops in any given crop cycle hence using seeds from informal sources. The few seed industries in Kenya do not produce adequate seeds of soybean to meet the demand and most of them have given priority to cereals or high value crops for them to make profits (Lowaars *et al*., 2012). A baseline survey conducted by Odendo *et al*., (2008) revealed that most farmers in Western region of Kenya had interest in growing soybean but had a challenge in accessing improved varieties and good quality seed during planting. In turn, the farmers resorted to using farm saved seeds and those they obtained from the local markets within their locality. Clayton *et al*., (2009) reporting on canola an oil crop like soybean cited rising cost of inputs of seeds, financial constraints and lack of knowledge of seeding as major constraints. In addition, lack of adequate and quality seed supply by the formal system and limited technical support to promote the informal seed system have hindered farmers from accessing improved quality seeds (Oshone *et al*., 2014).Similar findings were reported by Oshone *et al*., (2014) that majority of the farmers in Ethiopia obtained common bean seed from informal sources a channel which contributed more than 95% of the common bean seed supply in Ethiopia. Rubyogo, (2010) reported that over 90% of small holder farmers continue to meet their seed demand using uncertified seed. In Bangladesh, 25% of okra seeds another legume was produced by seed companies and agricultural corporations, another 25% was imported and the remaining 50% of seeds used were sourced from the farmers (Rahman *et al*., 2017). In addition, Houngnandan and colleagues (2015) reported that 90% soybean farmers in Benin used seeds saved from the previous season harvest or those from the nearby markets. Chianu *et al*., (2009) also conducted a survey in Kenya and revealed that most farmers used farm saved seeds or seeds sourced from the open air markets which at times were of mixed varieties to raise crops the following season.

Among the four varieties of soybean grown by farmers SB 19 (TGx 1744-2F) was the most preferred variety across the different zones in Busia County due to its high yielding and early maturity qualities. Similar reports were made by Mahasi and others (2011) who found that SB 19-(TGx 1744-2F) was the only variety which performed excellently across different locations and did better than the existing varieties. According to Chianu and colleagues (2008) TGx varieties were high yielding with nitrogen fixation capabilities. Similarly, Sanginga and collegues (2003) reported that the dual purpose soybean varieties were particularly good in both nitrogen fixing and mulch materials. In addition, Mahasi and others (2011) reported that Tropical Grain Crosses (TGx) 19 and 8 dual purpose varieties developed by IITA were released in Kenya because of their ability to fix nitrogen, high biomass and grain yields. Farmer participatory variety selections carried out in Busia, found that apart from the high yields, SB 19 adapted well to different agro-ecological zones and superior over the checks (Mahasi *et al*., 2011). In addition, SB 19 was the most planted variety as it was preferred by Promasidor because it met factory requirements of high protein content and protein to oil ratio of 2:1 (Collombet, 2013).

Among the constraints reported by the interviewed farmers, poor germination and disease were the major constraints. The use of retained , untreated and poor quality seed by small scale farmers encourage the spread of seed-borne pathogens resulting in build-up of inoculum which lead to outbreak of disease epidemics (Icishahayo *et al*., 2007). The use of low quality seed results to poor emergence and plants with low vigour (Matthews *et al*., 2012).Similarly, Ronner *et al*., (2016) reported that bean fly, dung beetle soybean rust, peanut mottle, leaf rust, and nematodes were the major pests and diseases of soybeans in Kenya that resulted from the use of seeds from informal sources. Low quality seed from informal sources was also reported by Chirchir *et al* (2016) as a constraint that hamper soybean production in Kenya due to reduced stand establishments.

Majority of the farmers over 60% preferred to grow soybean in pure stands. Sole crop proved easy to manage and had no nutrient competition with other crop compared to intercropped crops. Farmers reported that soybean was suitably grown in pure stands during the short rainy season which starts in August to December. During this period there was less impact of maize streak virus and soybeans could survive due to its high drought tolerance capacity (Chianu *et al* 2008).Similar findings were reported by Mathu *et al*., (2010) that soybean grew at its best when grown in pure stands. On the contrary, Chianu and others (2008) reported that over 70% of soybean crop was intercropped with either maize or sugarcane in Western Kenya and 30% was grown under pure stands.

3.6.2 Post-harvest handling practices adopted by farmers in Busia County

Methods of threshing influence seed quality of soybean. Mechanical threshing causes more damage compared to manual threshing. Majority of the farmers interviewed reported to thresh soybean with sticks. As a result farmers experience a challenge in reduced germination and vigour of soybeans. Threshing techniques like machine and stick beating produced more breaks, cracks, bruises and abrasions which resulted in reduced germination, seedling vigour and increased number of abnormal seedlings as also reported by Reddy *et al*., (1995). Lack of knowledge on the sensitivity of soybean led to farmers using inappropriate post-harvest handling techniques like stick threshing. The few that were aware due to extension services in the region used hand threshing. Similar findings by Surve *et al*., (2015) indicated that hand threshed soybean recorded minimal physical damage and high germination compared to stick beating and mechanical threshing. Similarly, Jha *et al* (1995) reported that hand threshed soybean seed had higher viability and lower indices of seed coat damage than machine threshed seed. Hand threshing of soybean significantly increased seed yield compared with stick threshing and mechanical threshing (El-Abady *et al*., 2012).

Survey findings indicated that majority of the farmers did not treat their seed during planting or before storage. Untreated seeds act as vehicles of transmitting pathogens which cause diseases in soybean seeds. These pathogens affect germination and seedling vigour and as a result lower emergence and productivity (Sinclair, 1991). Treatment provide additional assurance to crop establishment at reduced cost and allows germination of infected seeds by controlling pathogens and protecting seed from soil fungi (Araujo *et al*., 2005).

Survey results revealed most of the respondents stored their seeds for a maximum period of three months and the second best storage period being six months. Studies have shown a gradual decrease in germination and vigour of soybean cultivars with increasing period of storage up to six months (El-Abady *et al*., 2012). The observed reduction in percentage germination and seedling vigour over time could be linked to depletion of reserved food for the embryo. This is in line with the findings of (Iqbal *et al*., 2002) and (Demirkaya *et al*., 2010) that reduction of viability and vigour could be attributed to a reduction in enzyme activity within the seed. In addition, the reduction in seed quality with time could be as a result of membrane degradation (Singh and Dadlani, 2003), reduction in enzyme activity or changes in chemical composition of the cell (Verma *et al*., 2003). Similarly, extending storage period intensified deterioration hence low productivity of soybean (Adoba *et al*., 2016). Belesevic and others (2010) found that storage conditions and durations affected germination and seed vigour. According to Arif and others (2006) seed viability decreased gradually from 64.5% to 39.2% as duration of storage increased from 2 months to 12 months. Similarly, Bortey *et al*., (2016) found that germination and seedling vigour of cowpeas declined with increase in storage duration irrespective of genotypes or storage materials. More decline in germination of soybean stored under conventional condition due to variable temperature and humidity was also reported by Balesevic-Tubic *et al* (2010). If the seeds were not dried properly high moisture content reduced seed viability by promoting fungal growth (Pradhan and Badola, 2012) which further resulted in reduction of germination.

On the contrary, Wang *et al*., (2010) reported an increase in seed germination and vigour with an increase in duration of storage of some subalpine woody species like *Betula utilis* and *picea purpurea*.Similarly, Azadi and Younesi (2013) also reported that an increase in duration of storage caused a decrease in the enzyme activity of sorghum seeds.

As a conclusion, oil crops such as soybeans and sunflower, increased content of fatty acid and auto oxidation of lipids during storage were the main causes of rapid deterioration of oil crops seeds (Balasevic-Tubic *et al*., 2005).

3.6.3 Effect of seed source on analytical purity of soybeans

Analytical purity of seed from different sources in different agro-ecological zones varied significantly. Samples obtained from informal seed sources did not the minimum recommended purity standard of 98%. Seeds collected from agro-dealers were more pure as compared to seed from local market and farmers. The use of sophisticated machines and a number of inspections in the formal seed syatem ensured high quality of seeds throughout the system. The presence of seed regulations and standard procedures in the formal sector also ensures maintenance of high quality status on seeds. Similar observations were made by Rahman and colleagues, (2017) that okra seeds obtained from seed companies were more pure followed by those from government organizations and then the farmer's seeds. Bishaw *et al*., (2012) working on barley also observed that seeds obtained from the formal sector had the highest analytical purity as compared to those collected from the farmers and local markets. On the contrary, high analytical purity was reported for wheat seeds samples collected from farmers (CIMMYT, 1999) and for sorghum in Ethiopia (Mekbib, 2008). The use of non-cemented floors and lack of careful attention during threshing resulted in accumulation of foreign materials in farm saved seeds of Okra as reported by Rahman *et al*., (2017). Fujisaka *et al*., (1993) found that rice seeds samples from farmers who used manual harvesting and threshing had higher analytical purity compared with those that were machine harvested.

The present findings indicated that seeds from the informal sources recorded higher percentage of damaged seeds compared to seeds from the formal sector. The damaged seeds had low seedling vigour and germination capacities hence reduced seed quality. Reddy *et al*., (1995) reported that seed damage during threshing of soybean resulted in shorter storage life of seeds. Costa *et al*., (2005) studying on zoning soybean crop found out that the spoilage caused by physical injury and moisture content were the main factors that contributed to reduced quality of soybean seeds. Similarly, seed coat damage was considered the most common reason for poor quality in most legumes especially when threshed at unsuitable seed moisture content (Greven *et al*., 2001). The best physical and physiological qualities with reduced physical damage were obtained at 14.1% seed moisture content as reported by Souza *et al*., (2002). Pacheco *et al*., (2015) pointed out that physiological quality, seedling vigour and performance of soybean seeds was highly influenced by seed coat injury.

3.6.4 Effect of seed source on moisture content, seed coat and insect damage of soybeans

Soybean seeds obtained from informal sources had increases physical injuries as farmers had poor knowledge on seed coat sensitivity of soybeans. Minimal injuries on seeds from the formal sources may be attributed to improved and planned processing technology and knowledge of handling soybean. Seed processing is a key component in any planned seed production program which targets improved seed characteristics (Araujo *et al*., 2008). Damaged seeds have a shortened shelf life and eventually result in poor emergence and crop stand. The cracks on the seeds may also become entry points of microorganisms and insects which reduce the storage potential and the general quality of the seeds (Marcos Filho, 2005). Moisture content of seed samples obtained from different sources across the agro-ecological zones was not significant. However seed moisture content is an important factor that determines the extent of damage and storage life of any seed. Similarly, Kavak *et al*., (2012) concluded that high moisture content reduced the physical and physiological quality of seeds and low moisture content increased mechanical injury on the seed.

3.6.5 Effect of seed source on germination and seedling vigour of soybeans

The results indicated higher percentage germination in seeds from the agro-dealer a formal sector as compared to those from the informal sources. The high quality of seeds from the formal sector may be due to the fact that they have equipment and knowledge of handling seeds. According to Adetumbi *et al*.,(2011) the formal sector is well equipped with sophisticated equipment and skills of handling seeds to ensure that the quality of seed is maintained all through. One major quality control mechanism that has been instituted in the formal seed sector is regular seed inspection at different levels from seed field to distribution channels. This has ensured that the quality of the seed is maintained from the field all the way to the hands of the final consumer which is the farmer. Similarly Bishaw *et al*., (2012) reported that percentage germination of certified seed from the formal sector was higher compared with seed obtained from other farmers, local markets and own saved seeds. Germination percentage of seeds from farmers was comparable to the minimum standard. Similar results were also reported in Ethiopia where almost all samples collected from the farmers reached the minimum germination standards for wheat (Ensermu *et al*., 1998) and sorghum (Mekbib, 2008). Bishaw *et al* (2012) in his studies also found that certified seed had significantly higher germination in Lentils compared with seeds from other sources.

On the contrary, Hassan (1995) found no significance differences in germination between certified wheat seeds and those obtained from other farmers or own saved seed. Similarly, Ndjeunga (2002) also reported average germination for sorghum seed samples collected from farmers in Niger with no differences across agro-ecological zones.

3.6.6 Effect of seed source on fungal seed infection of soybeans

The findings indicated that seeds obtained from the local market and own saved were more infected as compared those from the agro-dealers. This was due to unhygienic storage conditions at the farmer's level (Utoba *et al*., (2011). The formal sector also practices seed treatment using fungicide, insecticides or combination of different chemicals which protect the seed from infections. Seed dressing protects the growing seedling for a specific period helping it escape infection. According to Ellis *et al*., (2011) seed treatment has been adopted worldwide to manage soybean diseases. This technique has shown significant improvement in field emergence, seed yield and reduced mycoflora association (Anuja *et al*., 2000).

The varied pathogen inoculums could be attributed to variations in climatic conditions during the crop cycle especially the prevailing humidity which favor the growth of the pathogens (Naqvi *et al*., 2013). *Cercospora kikuchii, Penicillium spp.*, *Aspergillus niger and flavus.* were observed as the most common fungal pathogens that infected soybean seeds in Busia County. These pathogens have been reported to be major seed-borne pathogens of soybeans (Bhale *et al*., (2004). Similarly, observations in pre and post-harvested soybean seeds were reported by Wu *et al*., (1964).

Presence of these fungal pathogens has shown maximum reduction in physiological potential of soybean seed (Krishnamurthy and Raveesh 1996; Galli *et al*., 2007). Fusarium and Aspergillus spp. are the most harmful pathogens responsible for germination, seed rots and post emergence decays of soybeans (Singh 1992; Koning *et al*., 1995). Similarly, purple stain caused by *Cercospora kikuchii* has been reported to cause 30% loss in seed viability and germination (Singh and Agrawal, 1986).

CHAPTER FOUR

EFFECT OF DIFFERENT METHODS OF THRESHING, DRYING, SEED TREATMENT AND DURATION OF STORAGE ON SOYBEAN SEED QUALITY AND YIELD

4.1 Abstract

Post-harvest handling practices affect seed quality which is a critical attribute that determines crop production. Soybean seeds have a very thin testa that is susceptible to physical damage which occurs during post-harvest operations. The seeds deteriorate further with duration of storage and eventually result to poor germination, seedling vigour, crop stand and yields. This study was therefore carried out to determine the effect of different threshing and drying methods, seed treatments and duration of storage on soybean seed quality and crop yields. Soybean crop was raised from a sample obtained from the farmers and after harvest, the produce was subjected to different methods of threshing like hand threshing, beating with sticks on the tarpaulin, rubbing the pods and beating inside the sack and thereafter dried in the sun, in an oven and under the shade drying methods. Stick threshing method and field drying were taken as the control. A sample of 50,000 seeds was drawn from the control and treated with cow dung ash, Apron star®, Monceren®, Root guard® and untreated seed as the control. Each seed treatment was assigned 10,000 seeds. The treated seeds were then stored for three months with planting being done at an interval of one month. Seed quality tests were conducted in the laboratory and data on seed coat damage, germination percentage, fungal seed infection and seedling vigour was collected. The results indicated that the methods of threshing and drying, seed treatments and duration of storage had significant effect on soybean seed quality. Hand threshed seeds, treatment of seeds with Cow dung ash, Monceren and Root guard and storage period of one to two months enhanced germination and seedling vigour while threshing with stick, seed treatment with Apron star and storage periods beyond two months reduced germination percentage and seedling vigour.

Inappropriate post-harvest handling techniques cause seed damages and cracks which act as entry point for pathogens which reduces seed quality through infections. Hand threshed and oven dried seeds had reduced seed coat damage, higher germination percentage, lowest percentage of fungal seed infection and high crop yields. This was attributed to minimal cracks and damage of seeds with adequate food reserve for germination and vigorous seedlings. It was concluded that post-harvest practices affected the quality of soybean seeds. Therefore, it is necessary to advise farmers to adopt hand threshing, oven or shade drying, seed treatments and shorter duration of storage to enhance germination, seedling vigour and crop yield for improved production.

Keywords: Soybean, threshing, drying, seed treatment, storage, seed quality

4.2 Introduction

Seed quality is a critical attribute that determine crop production (Cardoso *et al*., 2015). Soybeans have a very thin testa low in lignin providing little protection to the radicle beneath it (Gagre *et al*., 2014). Among legumes, soybeans due to their thin seed coats are susceptible to physical injury during harvesting and post-harvest handling (Shelar *et al*., 2008). Franca Neto and Henning (1984) also reported seed coat damage as one of the causes of great loss in soybean seed quality during harvest and post-harvest handling.

Rapid and uniform field emergence is also essential to achieve high yields of good quality crop and among the techniques that have been known to enhance seed quality of a variety of crops is seed treatment before storage. It has become an important practice incorporated into agricultural production which is done extensively in maize production and now progressing to soybean. It has been used to protect seed against both seed and soil-borne pathogens (Taha *et al*., 2013; Cardoso *et al*., 2016). The most important diseases of soybean are caused majorly by fungi transmitted by seed or soil. These pathogens negatively affect germination, seedling establishment and reduce crop stand and yield (Lucca Filho, 2003; Mertz *et al*., 2009). Since most of the seeds used by farmers are of poor quality and usually untreated they may harbor diseases and when planted may result to poor crop establishments, crop stand and yields.

Soybean seed quality deteriorates faster during storage than most of the crops like beans and maize due to its high oil content make up. During storage, damages caused by moisture and physical damage majorly contribute to decline in germination and seedling vigour of soybeans (Moreano *et al*., 2011). High seed moisture increases seed mycoflora which play a major role in soybean seed quality deterioration during storage (Shelar *et al*., 2008). As a rule of thumb, for each 1% reduction in moisture content of seeds with moisture content range of 6% to 20%, the storage period doubles (Harrington, 1960). Other factors like genetics, quality of seed at the time of storage and temperature of storage environment have been reported (Gupta, 1976) to affect seed quality. Seed germination and seedling vigour declined with increasing the duration of storage (Kurdikeri *et al.*, 2012). The aim of the study therefore, was to evaluate on the effect of post-harvest handling practices on soybean seed quality.

4.3 Materials and Methods

4.3.1 Effect of different methods of threshing and drying on soybean seed quality

4.3.1.1 Description of the study area

The study was carried out in in LM I and LM IV zones in Western Kenya, Busia County. LM I is also referred to as marginal sugarcane zone while LM IV is known as marginal cotton zone. The ecological conditions of this region are characterized by altitude range of between 1135-1500 meters above the sea level, annual rainfall range of 900-2000mm with a mean temperature of 21.5^{0}C. The soils are mainly a complex of well drained, moderately deep to very deep, reddish brown to yellowish brown, friable clay orthric Ferralsols with dystric Nitosols. The area experiences two rainy seasons with the long rains starting end of February to August and the short rains beginning in September to December (Jaetzold and Schmidt, 1982). The ecological conditions of these zones of interest are given in table below:

Table 4.1: Characteristics of two Agro-Ecological zones in Busia County

Agro-Ecological Zones	Altitude in Meters	Annual mean temperature in ^{0}C	Annual average rainfall in mm	60% reliability of rainfall	
				1st rains	2nd rains
Lower Midland I	1300-1500	20.5-21.7	1800-2000	800-900	650-800
Lower Midland IV	1135-1200	22.3-22.7	900-1100	<400-480	<100-220

(Jaetzold and Schmidt, 1982)

4.3.1.2 Production of soybean seeds

A sample of soybean seeds variety SB-19 (TGx1744-2F) collected from the farmers during the survey was used to establish soybean crop. Planting was done towards the end of August 2016 which marks the start of short rains in Busia County. The crop was established in 30m x 25m plots in both LM I and LM IV with a row spacing of 45cm by drill. Other agronomic practices used by the local farmers around the area of the study to raise the crop like weeding and cropping systems were adhered to throughout the crop cycle.

The crop was harvested at harvest maturity and subjected to different methods of threshing; hand threshing, beating with sticks, beating with sticks in a sack and rubbing the pods. A sample of 40,000 seeds (4Kg) was collected from each threshing method and each sample consisting of 10,000 seeds (1Kg) was dried in the sun, under the shade, in an oven set at 31^0C and field drying as the control. Field drying is using seeds from the field at harvest maturity without further drying after harvest. The seeds were then evaluated for seed coat damage, germination, fungal seed infection and seedling vigour.

A sample of 5000 seeds (0.5Kg) from each category was used to establish soybean crop in the field to evaluate the effect of threshing and drying methods on crop yield. Experimental plots measuring 2.5m by 2.5m with spacing of 45cm by 10cm were laid out in a split plot with three replications. Threshing methods were the main plots and drying techniques being the sub-plots. Two seeds were planted per hill and after emergence, five plants in each row were randomly tagged in any given plot for data collection on number of pods per plant, height of plants, Biomass and grain yield per plot.

4.3.1.3 Effect of different threshing and drying methods on seed coat damage

Seed coat damage was determined by Sodium hypochlorite soak test as per Van Utrecht *et al*., (2000) in completely randomized design. Four hundred seeds were soaked in

1% Sodium hypochlorite solution for 10 minutes. Seeds were considered to be damaged when the seed coat appeared wrinkled, swollen or with loose coats. Damaged seeds were counted and the estimate of seed coat damage was calculated using the formula:

$$\text{Percent seed coat damage (\%)} = \frac{\text{Number of damaged seeds}}{\text{Total number of seeds}} \times 100$$

4.3.1.4 Effect of different threshing and drying methods on seed germination and seedling vigour

Germination test was conducted according to ISTA 2015 guidelines on paper towel to determine the percentage of viable seeds for all the seed samples from the different threshing and drying methods. Seeds were surface sterilized in 2% sodium hypochlorite solution for five minutes to retard saprophytic fungal infestation followed by three changes of sterile distilled water. These were put for germination in four replications of 100 seeds each in transparent plastic boxes lined with absorbent towel. The seed were routinely misted with sterile distilled water to prevent them from drying up. Germinated seeds were counted for fifteen days at an interval of five days from the plating date. Seeds were considered germinated when 2mm of the radicals protruded and germination percentage calculated as shown below (Chirchir *et al*., 2016).

$$\text{Percent germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

In addition, Germination Rate Index (GRI) which is an expression of the total number of seeds that germinate in a time interval was calculated by the formula:

$$\text{GRI} = \frac{\text{No. of germinated seeds at the time of first count}}{\text{Days of first count}} \ldots + \ldots \frac{\text{No. of germinated seed at final count}}{\text{Days of final count}}$$

Seedlings were further grouped into normal seedling, abnormal seedlings according to their appearance. The essential features used to identify and group the seedlings into these two categories were the primary and secondary roots, hypocotyl, epicotyl and mesocotyl, coleoptiles and the cotyledons (ISTA 2015).

A seedling was considered normal if all the essential structures were intact, well developed and in proportion, or with slight defects and balanced development. Abnormal seedlings were those, with any essential structure missing or badly damaged, deformed, diseased or decayed that normal development would be interfered (ISTA 2015).

Seedling vigour was determined after 15 days by randomly selecting 10 seedlings from each replicate for each treatment and measuring the root and shoot lengths using centimeters ruler. These were then used to calculate the seedling vigour index as an expression of the potential level of activity and performance of the seed during germination and seedling emergence using the formula by Abdul Baki and Anderson, (1973).

Seedling vigour index (SVI) = Germination % x seedling length (root length + shoot length)

4.3.1.5 Effect of different threshing and drying methods on fungal seed infection

Forty soybean seeds per sample were surface sterilized in 2% sodium hypochlorite for three minutes, followed by rinsing in three changes of sterile distilled water and blot dried on sterile paper towel. Four replications of 10 seeds per petri dish were plated on Petri dish containing potato dextrose agar media and incubated for 3-7 days at 25^0c in alternating dark and light conditions (Alemu, 2014). Sodium chloride (13.4g/l) was added to the media to inhibit germination and 50ppm streptomycin sulphate to inhibit bacterial growth. The number of seeds infected and the individual pathogen types were recorded and results expressed as a percentage. Fungi growing on PDA plates were identified both visually and under the stereomicroscope by observing colony characters and morphology of sporulating fungi (Shovan *et al*., 2008).

4.3.1.6 Effect of different threshing and drying methods on soybean yields

Five thousand seeds (0.5Kg) from the different methods of threshing and drying was used to establish soybean crop in the field to evaluate the effect of threshing and drying methods on yield. Experimental plots measuring 2.5m by 2.5m were laid out in a complete randomized block design in split plot arrangement with three replications. Threshing methods were the main plots and drying techniques were the subplots. Five plants were tagged in each plot for data collection on number of pods per plant, height of plants, Biomass, grain yield and harvest index.

4.3.1.7 Effect of seed treatment and duration of storage on germination and seedling vigour of soybean

Two soybean varieties SB19 and SC Squire which were less than three months old were subjected to different seed treatments and duration of storage. The seeds were divided into five 300g samples with each sample being treated with different seed treatments. Seed treatments were; cow dung ash, Apron star® WS (20g/Kg Difenoconazole + 200g/Kg Metalaxyl + 200g/Kg Thiamethoxam), Monceren® (Imidacloprid 233g/L + Pencycuron 50g/L + Thiram 107g/L), Root guard® (Trichodema + Bacillus + Aspergillus + Chatomium + Eschirichia + Azotobactor) and untreated seeds as the control. Seeds were treated using manufacturers' recommendations rates of 10g/2Kg seed, 10ml/20ml of water, 50g/25Kg of seeds for Root guard® and a handful/Kg of seed for cow dung ash. A portion of seed from each treatment was planted immediately after treatment and the remaining portion was stored for three months with planting being done at monthly interval. The experiment was laid in a split-split plot arrangement in the laboratory with four replications. Variety was the main plot, duration of storage as the subplot and seed treatment as sub-subplot. Data on germination and seedling vigour was collected.

4.4 Data collection and analysis

Data on seed coat damage, germination, fungal seed infection, seedling vigour and yield were subjected to analysis of variance (ANOVA) using GENSTAT 15th edition and the means separated using Fischer's protected Least Significant Difference (LSD) at 5% level of significance (Steel and Torrie, 1960).

4.5 Results

4.5.1Effect of different methods of threshing and drying on seed coat damage

Methods of threshing and drying differed significantly in seed coat damage. Seeds that were hand threshed, shade and oven dried had the least percentage of seed coat damage as compared to the other methods of threshing and drying. All the threshing methods did not have significant effect on seed coat damage for seeds that were field and sun dried. There was reduced seed coat damage for seeds that were hand threshed and dried in an oven or under the shade (Table 4.2).

Table 4. 2: Percent seed coat damage of seed due to different methods of threshing and drying

	Drying methods				
Threshing methods	Field	Oven	Shade	Sun	Mean (Drying)
Removing seeds by hand	59.8a	44.8b	59.5b	65.5a	57.4b
Rubbing the pods	67.5a	66.0a	69.5a	67.8a	67.7a
Beating with stick in sack	60.0a	68.5a	67.0a	67.5a	65.8a
Beating with stick on the floor	64.3a	67.3a	68.5a	67.0a	66.8a
Mean (threshing)	62.9ab	61.6b	66.1ab	66.9a	64.4
Overall mean	64.4	64.4	64.4	64.4	64.4
LSD ($P \leq 0.05$) (threshing)	3.9	3.9	3.9	3.9	3.9
LSD ($P \leq 0.05$) (drying)	4.8	4.8	4.8	4.8	4.8
LSD ($P \leq 0.05$) (threshing x drying)	9.0	9.0	9.0	9.0	9.0
CV (%)	10.4	10.4	10.4	10.4	10.4

LSD=least significance difference, CV=coefficient of variation

4.5.2 Effect of different methods of threshing and drying on seed germination and seedling vigour

Germination percentage varied significantly with different methods of threshing. The highest germination of 90.9% recorded with seeds threshed by rubbing the pods and hand. Similarly seeds that were threshed using these two methods had the highest germination rate.

The drying techniques had no significant effect on percent germination but affected the germination rate. The highest number of normal seedlings was reported in hand threshed soybean seeds. Rubbed seeds had the lowest percentage of normal seedling despite high germination percentage. Seeds dried in the oven had the highest number of normal seedlings. Seeds threshed inside a sack and dried under the shade had the lowest seedling vigour (Table 4.3).

Table 4. 3: Effect of different methods of threshing and drying on percent germination and seedling vigour of soybean seeds.

Threshing method	Germination%	Germination rate	No. normal seedling	Seedling length (cm)	Seedling vigour index
Removing seeds by hand	93.9a	34.0ab	87.8a	6.9ab	6.6ab
Beating with stick in sack	87.6b	32.0c	81.3ab	5.7b	5.0c
Beating with stick on the floor	89.9b	32.6bc	81.9ab	6.5b	5.9bc
Rubbing the pods	93.9a	34.4a	78.4b	8.0a	7.5a
Drying methods					
Field drying	92.9a	34.1a	81.4a	7.5a	7.1a
Drying in an oven	91.4a	33.5ab	86.5a	6.6ab	6.1ab
Drying under shade	89.5a	32.5ab	80.8a	5.8b	5.3b
Drying in the sun	91.5a	32.9b	80.6a	7.2ab	6.6ab
Mean	91.3	33.2	82.3	6.8	6.3
LSD ($P \leq 0.05$) (Threshing)	3.2	1.5	7.6	1.3	1.3
LSD ($P \leq 0.05$) (Drying)	4.3	1.5	9	1.7	1.7
LSD ($P \leq 0.05$) (Thr. x Dry)	6.8	2.9	15.4	2.8	2.7
CV (%)	4.9	6.4	12.9	27.1	28.9

LSD=least significance difference, CV=coefficient of variation, Field drying- no further drying after harvest, Thr- threshing, Dry- Drying and, %- percentage and No.- Number

4.5.3 Effect of different methods of threshing and drying on seed infection with fungi

The methods of threshing and drying were significantly different on the levels of seeds infected with different fungi. Soybeans threshed by beating with sticks either on the floor or in a sack and those dried under the shade showed high levels of seed infection. Hand threshed and oven dried seeds had the least level of seed infection. There was no incidence of

Cercospora kikuchii on seeds that were hand threshed and oven dried. *A.flavus* was more prevalent, 13.8 and 11.3 on seeds that were hand threshed and dried under the shade respectively. The lowest incidence levels of *Aspergillus flavus and niger* was on seeds dried in the oven, 3.8 and 1.3 respectively. *Penicillium spp.* majorly infected seeds that were threshed by beating with sticks either on the floor or in a sack and dried in an oven (Table 4.4)

Table 4. 4: Percentage of fungi in soybean seeds subjected to different methods of threshing and drying.

Threshing methods	*Infected*	*C. kikuchii*	*A. flavus*	*A. niger*	*Penicillium spp.*
Removing seeds by hand	38.8b	0.0b	13.8a	10.0a	15.0ab
Beating with stick in sack	60.0a	21.3a	1.3b	10.0a	27.5a
Beating with stick on the floor	67.5a	23.8a	1.3b	15.0a	27.5a
Rubbing pods	57.5ab	21.3a	7.5ab	17.5a	11.3b
Drying methods					
Field drying	56.3b	23.8a	7.5a	15.0a	10.0b
Drying in an oven	32.5c	0.0b	3.8a	1.3b	27.5a
Drying under shade	72.5a	22.5a	11.3a	17.5a	21.3ab
Drying in the sun	62.5ab	20.0a	1.3a	18.8a	22.3ab
Mean	56.0	17.0	6.0	13.0	20.0
LSD($P \leq 0.05$) Threshing	16.6	13.1	9.1	11.7	13.2
LSD ($P \leq 0.05$) Drying	12.2	10.3	12.4	7.7	15.1
LSD ($P \leq 0.05$) Thr. X Dry	30.6	24.3	19.2	21.2	30.2

LSD=least significance difference, C-Cercospora, A-Aspergillus, Field drying- no further drying after harvest, Thr- threshing, Dry- Drying and, %- percentage and No.- Number

4.5.4 Effect of different methods of threshing and drying on soybean yields

Threshing and drying methods had significant effect on plant height and the grain yield. Soybean seed threshed by hand and those dried in an oven gave rise to tall plants and plants with more grain yields. Seeds threshed by hand and dried under shade and in the oven gave the highest grain yield per plot. Apart from hand threshing, the other three methods of threshing reduced yields and did not differ significantly. The number of pods, plant biomass and the harvest index did not differ significantly for all the treatments (Table 4.5).

Table 4. 5: Plant height and yield of soybean seeds subjected to different methods of threshing and drying

Threshing methods	Plant height (cm)	No. of pods/plant	Biomass (Kg)	Yield (Kg)	Harvest Index
Removing seeds by hand	51.7a	30.7a	1.3a	0.6a	0.3a
Beating with stick in sack	48.8ab	31.2a	1.4a	0.5b	0.6a
Beating with stick on the floor	46.8b	31.6a	2.1a	0.5b	0.3a
Rubbing pods	48.3ab	32.2a	1.4a	0.5b	0.4a
Drying methods					
Field drying	49.8a	30.8a	1.3a	0.5b	0.4a
Drying in an oven	49.1ab	31.6a	1.4a	0.6a	0.6a
Drying under shade	48.6bc	33.7a	2.2a	0.6a	0.4a
Drying in the sun	48.2c	29.7a	1.4a	0.5b	0.4a
Mean	48.9	31.4	1.6	0.5	0.4
LSD($P \leq 0.05$) Threshing	3.5	5.7	1.1	0.1	0.5
LSD ($P \leq 0.05$) Drying	0.9	5.4	1.5	0.1	0.4
LSD ($P \leq 0.05$) Thr. X Dry	6.1	10.8	2.2	0.2	0.7

LSD=least significance difference, CV=coefficient of variation, Field drying- no further drying after harvest, Thr- threshing, Dry- Drying and, %- percentage and No.- Number

4.5.5 Effect of seed treatment and duration of storage on germination and seedling vigour of soybean

Seed treatments and duration of storage had a significant effect on germination and seedling vigour. However, all the treatments gave more germination percentage than the 75% recommended standard. Monceren® recorded the highest germination percentage of 90.2% while Apron star® recorded the lowest germination percentage (87.7%). Comparing the treatments with the control, Monceren® and Root guard® enhanced germination, cow dung ash gave comparable germination percentage as the control and Apron star® reduced germination of soybeans. Germination rate of untreated seeds and those treated with Monceren®, cow dung and Root guard® was higher while those treated with Apron star® had the lowest rate. Germination percentage reduced with time as the duration of storage progressed towards three months and beyond. One to two months' storage period gave the highest germination percentage and germination rate while Zero and Three months storage durations gave the lowest germination percentage and rates (Table 4.6).

The untreated seeds and those of zero duration of storage gave normal and most vigorous seedlings as compared to all the other treatments. Seed treatment negatively affected the percentage of normal seedlings and seedling vigour. Untreated seeds had the highest percentage of normal seedlings while seed treated with Monceren® recorded the least percentage of normal seedlings. Duration of storage equally affected the number of normal seedlings and seedlings vigour negatively. As the seeds aged from zero to three months of storage and beyond seedling vigour and the number of normal seedlings reduced significantly. (Table 4.6)

Table 4. 6: Percent germination and seedling vigour of soybean seeds treated with different seed treatments and storage periods

Treatments	Germination %	Germination rate	No. of normal seedling	Seedling length (cm)	Seedling vigour index
Untreated	88.6ab	31.9a	24.1a	10.8a	9.6a
Cow dung	89.5ab	31.3a	12.1b	9.4b	8.2b
Apron star	87.7b	29.9b	11.6b	8.9b	7.7b
Monceren	90.2a	31.9a	8.8c	8.5b	7.6b
Root guard	89.6a	31.6a	12.1b	8.4b	7.4b
Duration of Storage					
Zero months	82.8c	29.0b	23.3a	13.9a	11.4a
One month	92.2a	33.1a	20.3b	11.2b	10.3a
Two months	93.1a	33.3a	10.7c	9.0c	8.4b
Three months	88.5b	29.8b	0.7d	2.5d	2.2c
Mean	89.1	31.3	13.7	9.2	8.1
LSD ($P \leq 0.05$) Treatment	1.8	0.8	1.6	1.2	1.1
LSD ($P \leq 0.05$) Storage	2	0.9	1.4	1.4	1.3
LSD ($P \leq 0.05$) Trt. x Str.	3.8	1.6	3.2	2.6	2.4
CV (%)	4.2	5.0	24.1	26.6	27.9

LSD=least significance difference, CV=coefficient of variation. Trt- treatment and str. - storage

4.6 Discussion

4.6.1Effect of different methods of threshing and drying on seed coat damage

Threshing and the drying techniques had significant effect on seed coat damage, moisture content and seedling vigour of soybean. Hand threshed seeds had minimal damage while the other three techniques had high physical damage on the seeds. Soybean seeds have a very thin sensitive seed coat that could develop cracks during post-harvest operations which reduces the seedling vigour (Wang, 2001; Parde *et al*., 2002) and the general quality of seeds (Paiva *et al*., 2000). Machine and stick threshing methods subject the seed to a higher pressure which may crack the seeds and damaging the embryonic axis that lies under the thin layer seed coat which offer very little protection as also reported by Franca-Neto and Henning (1984).Our findings corroborate those of Surve *et al*., (2015) who reported that hand threshed seeds had the least physical damage compared to stick beating on the floor. Jha *et* *al*., (1995) using hand, harvester and tractor methods of threshing, found that hand threshing method recorded less seed coat damage as compared to tractor and harvester.

4.6.2 Effect of different methods of threshing and drying on germination and seedling vigour

Threshing and drying techniques affected viability of soybean seeds. The methods that showed higher seed coat damage had reduced germination except for rubbed seeds. The reduction in germination and seedling vigour of damaged seeds may be as a result of damaged radicle located just under the thin and sensitive seed coat of soybean (Gargre *et al*., 2014). Soybean seeds have poor germination and field emergence as compared to other oil seed crops because of its composition and the thin structure of the seed coat that is susceptible to physical damage (Rupesh *et al*., 2012).Similar findings were reported by Pinto *et al*., (2009) who observed that seed coat damage accounted for most germination losses in soybeans. Delouche, (1974) also made similar observations that physical injury that occurred during threshing and drying caused cracks on the seed coat and the cotyledons lowering germination due to damaged embryo or food reserves. Hand threshed seeds recorded higher germination percentage and lower incidence of split and cracked seed coats (Green *et al*., 1966). In addition, reported that hand threshed soybean seeds had the highest germination percentage Surve *et al*., 2015 and seedling vigour (El-Abady *et al*., 2012).

4.6.3 Effect of different methods of threshing and drying on fungal seed infection

Hand threshed and oven dried seeds had minimal seed fungal infection. The cracks due to threshing may have acted as the entry points for fungal infection as damaged or broken seed coats provide easy access of micro-organisms into the seed which produce toxic substances that destroy seed cells hence its deterioration (Shelar *et al*., 2008; Malik and Jyoti 2013). Shade drying may have not reduced moisture to safe levels hence favoring growth of microorganisms. Higher percentage of micro-organisms were found in highly deteriorated seeds, high moisture content and those with low seedling vigour as the leachates provided the pathogens with a ready source of food for their growth (Lai *et al*., 1968). The less infection on oven dried seeds found could be attributed to the more energy absorbed by the seed in form of heat that killed the pathogens inside or outside the seed coat (Aldjadjiyan, 2010).

Similar findings were reported by Sangakara, (1988) that hand threshed soybean seeds had a relatively low seed infection. Seeds that were dried under the shade had high fungal seed infection. Similarly Shelar, (2008) reported that seeds with high moisture content encouraged fungal seed infection. On the contrary Shelar *et al*., (2008) reported that soybean seed infection increased with subsequent increase in storage period irrespective of threshing and drying techniques.

4.6.4 Effect of different methods of threshing and drying on soybean yields

The findings of this study indicate that different methods of threshing and drying have significant effect on plant height and grain yield. Among the methods of threshing used, hand threshing gave more grain yields. This was attributed to minimal damage of seed that occurred when using this technique. Oven and shade drying had a positive effect on yields and this may be due to the energy absorbed in form of heat killed pathogens on and in the seed making the seed to grow optimally without any infection. Similar observations were made by El-Abady *et al*., (2012) and Aldjadjiyan, (2010)

4.6.5 Effect of seed treatment and duration of storage on germination and seedling vigour of soybean

The different seed treatment used affected germination, seedling vigour and fungal seed infection of soybean. Among the different treatments used Monceren and Root guard enhanced germination and seedling vigour of soybeans while Apron star reduced germination and seedling vigour. Variation in germination and seedling vigour of soybean seeds due to seed treatment could be attributed to the different mode of action of the chemicals used and other effects like phytotoxicity (Cardoso *et al*., 2016). Monceren is a contact fungicide that is made up of two contact fungicide and one systemic insecticide while Apron star consist of two systemic fungicide and one systemic insecticide. Monceren consist of Pencycuron which is a lipophilic active ingredient which penetrates into plant cuticle and act by inhibiting mycelium growth of fungi, thiram a broad spectrum fungicide which act by inhibiting spore germination and mycelial growth and imidacloprid a systematic insecticide with trans laminar activity and with contact and stomach action. Apron star consist of Difenoconazole which is a broad spectrum systemic fungicide with a sterol demethylation inhibitor which prevents the development of the fungus by inhibiting cell membrane ergosterol biosynthesis, mefenoxam a systemic narrow spectrum fungicide which affect the activity of the RNA polymerases inhibiting ribosomal RNA synthesis and thiomethoxam a systemic insecticide which act by contact and stomach action (Davidse *et al.*, 1983). Spray volumes may also lead to phytotoxicity which can rapture soybean seed coat and inhibit the growth of the embryo and impair germination of seeds (Embarapa, 2011). Reduced physiological quality due to phytotoxic effect of the active ingredients of the chemicals used was also reported by Brzezinski *et al*., (2015). Enhanced quality was because treatment protects the seed and seedlings against pest and diseases maintaining physiological quality and seed health (Avelar *et al*., 2011) and improve establishment and yield (Gadotti *et al*., 2012). Balardin and others (2011) similarly observed that treating seeds benefited soybean plants by improving tolerance to stresses and increasing yields. Similarly, Patil *et al*., (2015) reported that seed treatment enhanced germination and vigour of chick pea. Seed treatment was found to increase germination, emergence and yield in Sorghum (Girish *et al*., 2004). On the contrary, the findings by Fessel *et al*., (2003), Aveling *et al*., (2012) working on maize showed that seed treatment significantly reduced germination and seedling vigour.

Duration of storage negatively affected germination, seedling vigour and fungal seed infection. Germination and seedling vigour reduced significantly with increased duration of storage. Tekrony and colleagues (1993) also reported that soybean seeds generally had a shorter storage life compared to crops like maize, rice, wheat etc. due to their genetic make-up and storage of such seeds beyond three months at room temperature resulted to reduced seed viability and vigour. The decline in germination was also attributed to the ageing effect which led to depletion of food reserves, increased enzyme activity, fat acidity and membrane permeability (Shelar *et al*., 2008). In addition, seeds stored in conventional storage environment, rapidly loose germination and seedling vigour due to a favorable environment which favour deterioration (Gupta, 1976). Kurdikeri *et al.,* (1996) similarly reported that viability and vigour of soybean reduced with increase in storage period. Soybean seeds treated with fungicides and stored for more than three months had lower germination and field emergence (Krohn and Malavasi, 2004; Pereira *et al*., 2011) and seedling vigour (Simic *et al*., 2007; Rupesh *et al*., 2012).

CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion

Majority of the farmers in Busia County obtained seeds from the informal sources which included local markets, other farmers and own saved seeds with none sourcing from the formal sector. This was attributed to low availability, and high prices of certified seeds. Similar observations were made by Bishaw *et al.,* (2012) on wheat and common beans. The low availability of seeds from formal sources is due to soybeans' greater sensitivity and fragility (Adetumbi *et al*., 2011). Since majority of the farmers obtained seed from the informal sources, they never treated their seeds before storage or planting.

A larger percentage of farmers across all the agro-ecological zones that were sampled threshed their crop after harvest with sticks. This resulted in seed coat damage of soybean seeds with the cracks acting as the entry points of microorganisms which reduced germination percentage, crop establishment and yield potential as also reported by Shelar *et al*., (2008) and Surve *et al*., (2015).The study also revealed that despite these farmers receiving extension services they had limited knowledge on post-harvest handling and sensitivity of soybean seeds. The results further showed that majority of the farmers had limited knowledge on storage of soybean seeds. The storage window reported was between three months and one year with majority of them storing seeds for three months and a few extending up to six months. Soybean seeds quality declined with increase in duration of storage irrespective of the storage conditions and seed treatment due to depletion of seed reserves resulting to poor germination percentages and less vigorous seeds as also reported by Joshi *et al*., (2014). A larger portion of the seeds was also infected with pathogenic and storage pathogens like *Aspergillus niger*, *Aspergillus flavus*, *Penicillium spp*. and *Cercospora* *kikuchii*. These pathogens reduced germination and vigour of seeds by causing seed and seedling decays. Similar observations on soybean seeds were reported by Malik and Jyoti, (2013).

The findings indicated that seed treatment improved the germination and seedling vigour of soybeans. However, seed treatment did not extend the longevity of the seeds in storage. Among the different chemicals used, Monceren® enhanced germination and vigour of soybeans while Apron star® suppressed it. This showed that contact fungicide were superior to systemic fungicides due to their mode of action. Similar reports were reported by Bradley, *et al*., (2008) on wheat.

The study showed that different handling techniques used affected the quality of soybean seeds. Stick, rubbing and sack threshing resulted in a larger percentage of seed coat damaged seeds while hand threshed seeds had minimal injury, better germination and vigour as also reported by Surve *et al*., (2015). Shade dried seeds registered a higher percentage of infection while oven dried seeds had the lowest percentage of infection. The low temperatures of the shade did not reduce the moisture content to safe levels favoring the growth of fungi while the high temperatures in the oven killed the pathogen inoculum in the seed (Aladjadjiyan, 2010).

5.2 Conclusion

Larger percentage of farmers from different agro-ecological zones in Busia County obtained seeds for the following season from informal seed sources. These seeds were found to have low germination and vigour, high infection incidence and physical quality that is below the ISTA recommended standard of 98% as compared to seeds from the formal sources. Since the sources were informal, seeds were not treated and the few farmers that treated their seeds adopted crude methods of seed treatment like ash with the least percentage adopting new techniques like treating seeds with Biofix. Despite the extension services they received, majority of these farmers had limited knowledge on handling and sensitivity of soybeans. They threshed seeds with sticks and stored them for an extended period. As a result, seeds developed cracks creating entry points for microorganism and damaging the embryo found just beneath the thin seed coat.

Post-harvest handling practices affect soybean seed quality. Hand threshing, oven or shade showed high germination percentage and seedling vigour, reduced seed coat damage and fungal seed infection. Seed treatment with contact fungicides and shorter duration of storage maintained high quality status of seeds and gave rise to healthy normal seedlings with high germination percentage of above 75%.

It is therefore advisable for the farmers to adopt the use of certified seeds from formal sources, appropriate threshing, drying, seed dressing with contact fungicides and shorter durations of storage for improvement of soybean production in the region.

5.3 Recommendations

Based on the findings the following recommendations were be made:

i. Farmers should be advised on using certified and treated seeds to improve on yields of soybeans.
ii. Farmers should be encouraged on the use of contact fungicide and systemic insecticides
iii. Extensive training should be done on appropriate post-harvest handling and sensitivity of soybean crop.
iv. Farmers should be encouraged to use hand threshing and oven drying for seed or use shade drying where oven might not be within their reach.

v. Further research be done on the effect of post-harvest handling on genetic quality and bacterial seed infection on quality of soybeans and cost-benefit analysis at farm level.

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APPENDICES

Appendix 1.1: Farmers' questionnaire

Serial No…………………

PROFILING SEED SOURCES AND POST-HARVEST HANDLING OF SOYBEAN IN BUSIA COUNTY

QUESTIONNAIRE:

(TICK WHERE APPROPRIATE)

Part 1:

A: Farmers Background Information

Name: ………………………..

Mobile no: …………………...

Village……………………

Age: ………………………….

AEZ……………………...

Altitude………………………

Longitude……………….

Latitude………………………

Date of Interview…………

B: Gender: Male | Female

C: Education Level:

Primary | Secondary | College | University | None

E: Gender of the head of homestead: Male | Female

F: Who owns the land: Community | Grandfather | Others (specify) | Mother | Father

G: What is the total acreage of land owned? ……………………..

H: Crops grown e.g. maize, wheat, millet:

Crops grown	Size (Acreage)	Ownership	
		Own	Rented

I: Rank the crops in order of importance as food crop and as a commercial crop

Crop	Food	Commercial

Part 2:

A: Soybean Seed Production

i. Which are the major varieties of soybean grown in this area?

ii. 1……………………. 2…………………… 3…………………..

4……………………

iii. For how long have you been growing soybean? ....

iv. Which variety do you grow mainly and for how long have you been growing it?

Variety…………………… Period……………………

B: Sources of seed: ☐ Own saved ☐ Neighbors ☐ Open air market

☐ Seed shop ☐ Others (specify)

i. Are the soybean seeds readily available? ☐ Yes ☐ No

ii. If No, which are the constraints in getting the seeds?

1) ……………………………………………………………..
2) ……………………………………………………………..
3) ……………………………………………………………..
4) ……………………………………………………………..

iii. How do you cope with the constraints?

1) ……………………………………………………………..
2) ……………………………………………………………..
3) ……………………………………………………………..
4) ……………………………………………………………..

iv. If farmer uses farm saved seeds,

What parameters do you look for when selecting the seeds?

1) …………………………..

2) ……………………………

3) …………………………….

4) …………………………….

v. Do you treat the seed before planting? Yes No

vi. If yes, indicate the method (s) used:

1) …………………………

2) …………………………

3) …………………………

4) ………………………….

vii. Which are the problems that you face when using farm-saved seeds?

1) …………………………

2) …………………………

3) …………………………

4) …………………………

viii. How do you cope with these problems?

1) …………………………

2) …………………………

3) …………………………

4) …………………………

C: If purchased from the seed shop,

i. Are the seeds certified? [Yes] [No]

ii. Which are the problems that you face when using certified seeds?

1) …………………………

2) …………………………

3) …………………………

4) …………………………

iii. How do you cope with these problems?

1) …………………………

2) …………………………

3) …………………………

4) …………………………

Part 3: Soybean crop production

A: Which crop(s) were grown in the last three seasons before growing soybean?

Long rains season (2015)……………… Short rains season (2015)…………….

Long rains season (2016) …………………

B: Soybean production statistics for the last three seasons:

Season	Area planted	Yield
Long rains (2016)		
Short rains (2015)		

Longs rains (2015)		

C: Which cropping system do you use in planting soybeans?

Single	Inter-cropping	Other (specify)

i. If inter cropping, which other crops do you grow together with soybean?

1) ………………………………
2) ………………………………
3) ………………………………
4) ………………………………

D: Which are the major constraints that you face in the production of soybean?

1) ………………………………….
2) …………………………………..
3) …………………………………..
4) …………………………………..

E: How do you cope with the constraints?

1) ………………………………….
2) …………………………………..
3) …………………………………..
4) …………………………………..

F: Which are/is the most problematic pest(s) for soybean?

1. ……………….. 2. ……………….. 3. ……………… 4………………..

G: How do you manage them?

1) ………………………………………………….

2) ………………………………………………….

3) …………………………………………………..

4) …………………………………………………..

H: Which is/are the most prevalent disease(s) of this crop?

1. ……………… 2. ……………… 3. ……………….. 4. ……………….

I: How do you manage them?

1) ……………………………………………………………

2) ……………………………………………………………

3) ……………………………………………………………

4) ……………………………………………………………

Part 4: Harvesting and Handling techniques

A: Which are the indicators for maturity of soybean?

Pod color	Leaf color	Seed color	Other (specify)

B: When do you harvest soybean? ....

i. Which is the preferred climate for soybean harvesting? ....

ii. At what stage do you harvest? ……………………………

iii. Which methods do you use to harvest your soybean?

1) …………………………

2) …………………………

3) …………………………

4) …………………………

C: How do you thresh your seeds? ……………………….

D: Do you dry your soybean seeds? [Yes] [No]

i. If yes, when do you dry your soybean seeds?

[Before threshing] [After threshing] [Before and after threshing]

ii. How long do you dry your seeds? ....

iii. How many times do you dry the seeds? ....

iv. To what moisture extent do you dry the seeds? ....

E: Do you sort and grade the seeds before storage? [Yes] [No]

If yes, what is the criterion used for sorting the seeds?

1) ………………………………….

2) …………………………………..

3) …………………………………..

4) …………………………………..

F: Do you treat the seeds before storage? [Yes] [No]

If yes, which treatment methods do you use?

1…………………… 2………………….. 3………………….. 4…………………..

G: Where do you store your seeds? ....

i. For how long do you store the seeds? ……………………

ii. Which are the storage materials used for storage?

1…………………….... 2…………………. 3……………………… 4………………….

iii. Do you take out the seeds and dry periodically during storage? Yes No

H: Which are the common problems that you face during the storage of soybean?

1) ………………………………….
2) …………………………………..
3) …………………………………..
4) …………………………………..

Part 5: Utilization and Market of soybean

A: Which are the uses of soybean in this area?

1) …………………………
2) …………………………
3) …………………………
4) …………………………

B: When do you sell your soybean produce? ………………….

i. How much of the total produce of soybean do you sell? ....

ii. Do you sell for subsistence or as seed? ....

iii. Where do you sell the seeds to?

Farmers Local markets Contract companies

Other (specify)

iv. At what prices do you sell for?

Subsistence	Seed

v. Do you get any assistance from the NGO's in the area? Yes No

THANK YOU

Appendix 1.2: Agro-dealers' questionnaire

Serial No.…………………

PROFILING SOURCES OF SOYBEAN SEEDS IN AGRO-DEALER OUTLETS IN BUSIA COUNTY

QUESTIONNAIRE:

(TICK WHERE APPROPRIATE)

Part 1: Agro-Dealers

A: Dealer information

Name of dealer: ……………………. Date of Interview……………….

Altitude: …………………………... Longitude……………………….

Latitude: ……………………………

AEZ: ……………………..............

B: Do you stock soybean seeds? Yes No

If yes, which are the varieties of soybean that you deal with?

1) ………………………………….

2) …………………………………..

3) …………………………………..

4) …………………………………..

C: Where do you source your seeds from?

1) ………………………………….

2) …………………………………..

3) …………………………………..

4) …………………………………..

D: Are the seeds certified? | Yes | | No |

i. If No, do you treat the seeds before selling to farmers?

| Yes | | No |

ii. If yes, which chemicals do you use to treat the seed?

1) ………………………………….

2) …………………………………..

3) …………………………………..

4) …………………………………..

E: In what package sizes do you stock your seeds?

1 Kg	2 Kg	5 Kg	10 Kg	25 Kg

F: What are the prices per package size?

1 Kg	2 Kg	5 Kg	10 Kg	25 Kg

G: How do your store your seeds? ....

H: Which are the storage materials used?

1) ………………………………….
2) …………………………………..
3) …………………………………..
4) …………………………………..

I: How long do you store your seeds? ....

J: Do you offer extension services to the farmers? Yes No

If Yes which one?

1) ………………………………….
2) …………………………………..
3) …………………………………..
4) …………………………………..

K: How is the seed business? ....

THANK YOU