QUALITY AND SUPPLY OF FINGER MILLET SEEDS IN SOIN DIVISION OF KERICHO COUNTY

BY

DAVID KIPLANG'AT NG'ENO

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DECLARATION

DECLARATION BY THE CANDIDATE

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DAVID KIPLANG'AT NG'ENO

AGR/PGC/01/06

Signature……. Date……..…….

APPROVAL BY THE SUPERVISORS

I/We confirm that the work reported in this thesis was carried out by the candidate under my/our supervision.

Signature……..…….. Date……..….

PROF. OCHUODHO, J.O.
Department of Crop, Seed and Horticultural Sciences
School of Agriculture and Biotechnology
University of Eldoret, Kenya

Signature……..…….. Date……..….

PROF. MATHENGE, P
Department of Crop, Seed and Horticultural Sciences
School of Agriculture and Biotechnology
University of Eldoret, Kenya

DEDICATION

This work is dedicated to my wife Jennifer and the children for allowing me to carry out the research and being away from them most of the time.

ABSTRACT

Finger millet production in Soin division of Kericho County has been low due to seeds of unknown quality which farmers produce and use. The objectives of this study were to establish sources of finger millet seeds used by small scale farmers, determine the quality of finger millet seeds and the effect of farmers' practices such as; seed selection, processing and storage on seed quality. A survey was done and questionnaires were distributed using snowballing technique and a total of 177 farmers responded. Information on location of residence, level of education of the farmer, experience in farming and methods of seed selection, processing and storage was sought. Seed samples were collected and assessed for purity, seed germination, germination index, electrical conductivity, accelerated ageing, seed moisture content and seed health. Data analysis for the survey was summarized as frequencies and percentages while seed quality tests were assessed using the one way analysis of variance (ANOVA) and Kruskal Wallis test. The seed test results that showed statistically significant differences in their mean values ($P<0.05$) using ANOVA were further subjected to the Bonferroni Multiple Comparisons Test while those differences obtained using Kruskal Wallis ($P<0.05$) were further subjected to Wilcoxon Rank Sum Test. The distribution of the farmers in the division was even in all the six locations and 88% of the respondents sourced their seeds from the informal seed supply. Twenty-two percent obtained their seeds from the formal seed supply. At most 65% of them had primary level of education but interestingly had a wider experience in the growing of finger millet. About 7% of the respondents obtaining seeds from the seed company reported that the seeds were early maturing.All the other seed quality properties from the informal seed supply except for the percentage moisture content showed lower values when compared to the control (certified seeds). Existing knowledge show that smoke enhances seed germination but this study observed that seeds stored above fire places had the lowest germination percentage. Excessive heat was suspected for this observation. It was therefore concluded that most finger millet farmers in Soin Division sourced seeds from the informal sector and that different methods of producing seeds affected seed quality properties. The study recommended that finger millet farmers from this division be equipped with knowledge on the importance of using quality seeds through training on seed selection criteria and proper post-harvest handling of the seeds.

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ABBREVIATION

AAT	-	Accelerated Ageing Test
ANOVA	-	Analysis of Variance
CGIAR	-	Consultative Group on International Agricultural Research
CAP	-	Stands for a chapter as in the Laws of Kenya
DAEO	-	District Agricultural Extension Officer
DAO	-	District Agricultural Officer,
EC	-	Electrical Conductivity
EPZ	-	Export Processing Zone
FAO	-	Food and Agriculture Organization
GoK	-	Government of Kenya
GI	-	Germination Index
FOSS	-	Farmers Own Saved Seed
ICARDA	-	International Center for Agricultural Research in the Dry Areas
ICRISA	-	International Crops Research Institute for the Semi-Arid Tropics
KARI	-	Kenya Agricultural Research Institute
KES	-	Kenya Shilling
KAM	-	Kenya Association of Manufacturers
KNO_3	-	Potassium Nitrate
MDGs	-	Millennium Development Goals
MOA	-	Ministry of Agriculture, Nairobi
HM	-	Harvest Maturity
PM	-	Physiological Maturity
MC	-	% Moisture Content
STAK	-	Seed Trade Association of Kenya

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DEFINITION OF TERMS

Selection-A certain way in which farmers identify seeds basing on some criterion. In the context of this study selection of seeds was seen to have taken place in three stages namely; in the field, from harvest and from grains meant for food.

Processing-It is a term used to describe the technology of cleaning seed and preparing it ready for sowing or for market by the farmers.

Storage- A way in which farmers saved seeds for the next sowing season

Seed Quality– It is worthiness or superiority or excellence of a seed as material for next regeneration of a plant.

Source- Can be stock, supply or starting place where farmers obtain seeds

Seed production practices-These were the techniques used by the farmers to produce the seeds and include selection, processing and storage

Moisture content-The amount of water contained or held by the seeds

Accelerated ageing-It is a test done with the stress of high temperature and moisture subjected to the seed in order to force ageing.

Seed health-It refers to the presence or absence of disease causing microorganisms in the seed. In this study the seed sample that had the highest number of infection was said to be of low quality

Purity-Wholesomeness, Cleanliness of a seed lot

Vigor test –It is a test performed on a seed lot to predict its general ability to germinate over a range of adverse conditions

Seed test-It is a means by which the physical and physiological quality of a seed lot is assessed and measured.

CHAPTER ONE

INTRODUCTION

1.1Background Information

For agricultural sector to contribute to the national economy and improve the status of food security, significant investment in agricultural research and seed supply system should be emphasized (ICARDA, 2002).Almost 90% of the entire world's food crops are grown from seeds (Schwinn, 1994) and 75% of the world's food supply comes from consumption of seeds from crop species, mainly in the family Poaceae (TeKrony, 2006).

Seeds provide the major means of propagation by which genetic improvements in crops by plant breeders redelivered to the farmer (TeKrony, 2006). It is the embodiment of genetic information and a central resource on which best agronomic practices act upon to optimize crop productivity (Kelly, 1994; Omanya *et al.*, 2009).

Good seeds must have better germination as an essential process in plant development to obtain optimal seedling numbers that result in higher seed yield (Kaydan and Yagmur, 2008; Wekundah, 2012). Seeds must have certain qualities to guarantee the success of a crop notwithstanding other environmental conditions.

Seed quality is one of the critical factors that greatly influence performance in seed propagated crops as it forms the basis in the initial stages of crop establishment (Opole, 2006). Seed quality comprises the sum of all properties or characteristics which determine the potential level of the seed or seed lot performance and crop establishment. These include genetically, physical, physiological and soundness (microorganisms and insects) aspects (Marcos-Filho, 1998).

The use of quality seeds along with other inputs as well as appropriate cultural management practices is recognized as the most cost effective way of increasing crop production and productivity which have significant advances in food production

(KEPHIS, 2006). The availability of quality seeds of a wide range of varieties and crops to Kenyan farmers is very important to improve crop production and achieve food security in the country (Ednar *et al.*, 2006). The major challenge has been an attempt to develop a seed system that encourages wider use of quality seed at all levels to tackle poverty and food security.

1.2 Kenyan Seed Industry Structure

The Kenyan seed industry has developed into a vibrant regional leader with 67 seed enterprises currently operating (Wekundah, 2012). Seed supply system in Kenya is categorized into two viz; Informal and Formal seed supply. The informal seed supply system relies on individual farmer's knowledge with limited or in most cases no scientific intervention and usually target household needs but supplies 80 % of the seeds for planting purposes in the country (Ednar *et al.*, 2006; Wekundah, 2012).

Formal seed supply system employs specialized and scientific approach in its production and usually targets a big market. It has self-regulating as well as self-sustaining associations that have been formed to instill code of practice and ethics. It also updates its members with knowledge on seed position in the country (STAK, 2007).

The current seed regulations only recognize seed from formal source even though the informal source has the potential to be expanded in scope and quality to help farmers do better selection of retained seed ,improve quality of seed locally selected for sale and to promote more active trade in locally selected seed (Ayieko and Tschirley, 2006**).**

Currently, there are about eight major seed production and marketing companies supplying seeds to the domestic and regional export market in Kenya. The companies produce maize, wheat, sorghum, millet seeds among others. Their handling capacities are detailed in table 1

Table 1: Amount of small grain seeds handled by seed companies in Kenya.

s/n	Name of company	Type of seeds	Handling capacity in tons
1	East African Seed Co Ltd	Maize	390,000
2	Farm Chem Ltd	Maize	257,000
3	Kenya Seed Co Ltd	Maize, wheat ,sorghum, millet	10,178,000
4	KARI Seed Unit	Maize ,wheat, millet	66,300
5	Monsanto(K)Ltd	Maize	200,000
6	Pannar (k)Ltd	Maize	28,000
7	Western Seed Co	Maize sorghum	874,400
8	Lagrotech Ltd	Sorghum ,maize	26,000

Source: *Ministry of Agriculture, 2004* In: Grain Production in Kenya, EPZ, 2005

1.3 Outstanding Attributes of Finger millet Seeds

Finger millet is highly selfing (Dida *et al*., 2006) and its genetic composition is relatively stable over a number of years. However, variations and non-uniformity of the next crop at farmer's level has been noticed as a result of mixing up of the seeds during harvesting and sowing. Finger millet is also called a "famine" crop because it can be stored for many years. This is because the seeds are small, dry out quickly at maturity, and insects cannot live inside them. They can be stored as grains for long periods without insecticides. As a crop that has great merit of being able to store for long periods without deterioration or weevil damage, it stood out to be an important famine crop in Uganda during the British administration (Purseglove, 1985).

The presence of hard glumes and high silicon content in the grains protect them from moisture and insect damage (Kute, 1995). Stability of the finger millet grains and /or seeds over longer periods is attributable to higher carbohydrate content (78.01%) and lower lipid content (1.5%) (Sehmi, 1993). The presence of large quantities of sugars,

especially disaccharide and oligosaccharide compounds provide desiccation tolerance and structural stability of organelles, membranes, enzymes and proteins, other macromolecules, and the glassy state (Marcin and Ralph, 1994; Ralph, 1997; Gary *et al*., 2001).

The seed storage compounds that include proteins, carbohydrates, lipids, hormones, tannins, alkaloids, glycosides, phytin, vitamins and biotin have influence in seed performance. Their effects could account for differences in seed performance as the said substances are later remobilized during germination when new structures such as radicle are forming (Shewry *et al.,* 1995; Ochuodho, 2005).

Seeds, however, deteriorate and lose their viability during prolonged storage and become unfit for further production (Sudha *et al*., 2005). The deterioration of seeds is occasioned by lipid peroxidation (McDonald, 1999). This is because of the presence of free radicals that play a central in promoting molecular damage under the widest range of environmental stresses (George, 1993). This process is favored by moisture content beyond 14%. The moisture content maintained at between 6% and 14% coupled with low lipid level may explain why finger millet grains and /or seeds stay for longer periods when they are still viable.

1.4 Production and sales of finger millet seeds in Kenya during 2002-2006

The production of certified seeds of finger millet in Kenya in the period 2002-2006 was averaged at 648.2 kg year^{-1}(Annonym., 2007a) though it was only the year 2006 that recorded a production of 3242tons. This volume of certified seeds was quite dismal. This implied that majority of the farmers sourced their seeds from the informal sector.

In Kericho town, which is the headquarters of Kericho county and district, were shops from which small scale farmers purchased farm inputs from them. The leading merchants were Kenya Seed Company depot, Kericho wholesalers, Mutai wholesalers' Paksons, Mashambani, and Kipsigis wholesalers.

The sales of certified seeds of finger millet to small-scale farmers from 2002 to 2007 are presented in the bar graph (Figure 1).

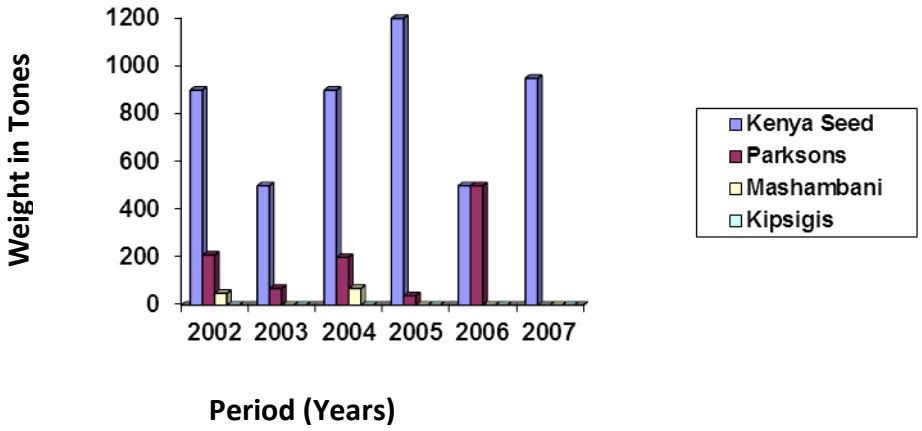

Figure 1: Distribution of certified seeds of finger millet by merchants in Kericho town over 2002-2007 periods

Average annual amount of certified seeds of finger millet over the same period was 250 kg against the national figure 648 tons (calculated from fig no.1), which translated to 0.04% of the national figure. This figure represented the quantity sold to the small-scale farmers in the entire Kericho district meaning therefore that the quantities of certified seeds of finger millet sold to small-scale farmers in Soin division were almost negligible.

1.5 Problem Statement

In Kenya, the production of finger millet has been constrained by a number of factors such as low research priority, limited uses of the crop, difficulty in management, lack of improved varieties and no certified seeds, poor crop husbandry, competition from other crops with better economic returns, and lack of commercial food products (Mitaru *et al.*,

1993; Kute, 1995; Oduori, 2005). Consequently the yields were variable and generally low, just about 15-16 % of theoretical maximum in Kenya (Takan *et al.*, 2002).

Finger millet hectarage in Kenya has been declining since 1978 with a greater variation in hectarage than production (Mburu, 1989) with grain yields ranging between 500-750 kg ha^{-1} (Mitaru *et al*., 1993). Yields of between 3.8 – 4.0 tons ha-1 have been observed in yield trials in Kenya (Oduori, 2005). Under irrigation and with improved seeds, yields up to 5-6 metric tons ha^{-1} have been obtained (Dida *et al*., 2006). However, the production of the crop from 2002 to 2006 in Kenya has averaged at 603kg ha^{-1} (Annonym. 2007a).

Finger millet was one of the cereals grown by small-scale farmers in Soin division of Kericho County (Annonym. 2006). This area had a total of 1100 small-scale farmers that grew finger millet. The production of the crop in terms of area under crop cover as well as grain yield was low (Annonym. 2007b). The production of the crop in Soin division has mainly been constrained by many factors among them being poor agronomic practices, non-use of fertilizers and use of seeds of unknown quality. Low use of certified seeds by small-scale farmers was responsible for the gap between potential farmers' yields and actual crop yields at farm level (Chianu *et al*., 2008). The scenario agreed with earlier studies that so far commercial production of the seed was limited (Kute *et al*., 2000).

Thus greater proportion of the farmers in Soin division used seeds whose quality was suspect and needed to be investigated with a view to suggesting improvements. The continued use of the said seed would be disastrous for the future production of finger millet in Soin division.

1.6 Conceptual framework

According to Orodho (2009); Oso and Onen (2009), a conceptual framework is a diagrammatic presentation of variables or theory/theories, illustrating and explaining their

interrelationships. Seed quality in this study was seen to be directly influenced by three main variables namely; seed selection, seed processing and seed storage as represented in Figure 2.

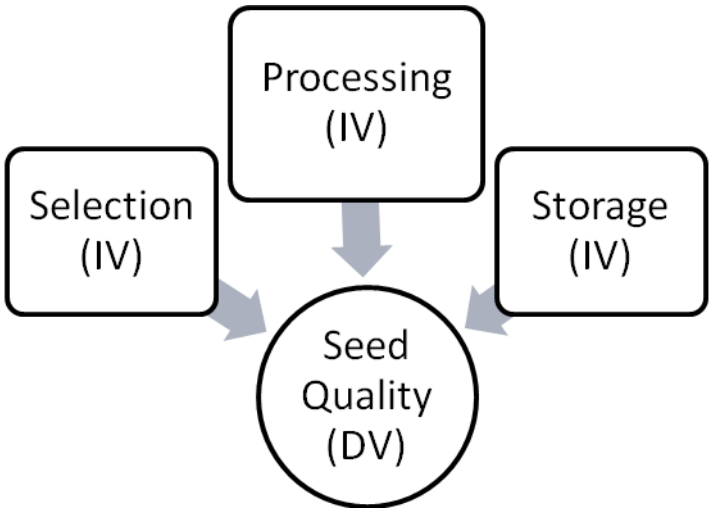

Figure 2: Relationship between variables that influence seed quality: (IV-Independent variable and DV-Dependent variable)

1.7 Justification of the Study

The demand for more food necessitate better use of a broader range of the world's plant genetic diversity (Rao, 2004) and more importantly among the more than 2000 crops native to Africa (Kuta *et al.*, 2003).

With increasing world prices for cereals and especially for maize due to its decline in production, Kenya would be affected most as it is a net food importer and a way forward to mitigate this was to direct concerted efforts towards local food production (Annonym., 2007a). Of the options is using finger millet as a food security crop since it does well in semi-arid areas where other cereals perform poorly (Kute, 1995).

The use of quality seeds to boost crop production stands as the surest way to avert hunger and starvation in Africa (Mallya, 1992). It was therefore imperative to adopt practices that produce better quality seeds in this region so as to enhance food security.

1.8 Overall objective of the Study

The overall objective of this study was to investigate the quality and supply of finger millet seeds produced and used by small-scale farmers in Soin division of Kericho County.

1.8.1: The specific objectives of the study

1. To establish sources of finger millet seeds used by small scale farmers in Soin division
2. To determine the quality of finger millet seeds used by farmers in Soin division
3. To investigate the effect of seed selection, processing and storage on seed quality

1.9 Hypothesis

H_{01}: Small scale farmers in Soin division obtained finger millet seeds from same the source

H_{02}: The quality of the finger millet seed used in Soin was uniform

H_{03}: Farmers seed production practices did not influence seed quality

CHAPTER TWO

LITERATURE REVIEW

2.1 Worldwide Production and Importance of Finger Millet

Finger millet, *Eleusine coracana* (L.) Gaertn, is a widely cultivated crop of tropical and sub-tropical regions of the world (Sumathi *et al*., 2005) and is an important cereal food crop in Africa and South Asia (Upadhyaya *et al*., 2007). It does well in semi-arid regions and is being cultivated in parts of Africa and India for its valuable grain (Bisht and Mukai, 2001). It is a crop grown in varying temperatures and altitudes from sea level to 3000m asl (Kute, 1995). It is also found in warm temperate regions of the world from Africa to Japan and as well as Australia. It is one of the few special species of plants that currently supports the world's food supplies and it is grown in over 4 million ha worldwide.

About 95% of the world's millet area lies in the developing countries, mainly in Africa and Asia (Léder, 2004). India is the largest producer of the crop in the world and cultivates over 2 million hectares (Sumathi *et al.*, 2005). In Africa it is grown in the eastern and southern part of the continent (Oduori, 2005). The crop is documented in the archaeological records of early African agriculture in Ethiopia (NRC, 1996) and its domestication dates back to about 5000 years ago (Dida *et al.*, 2006) and is thought to have originated from the highlands of Ethiopia and Uganda. In some parts of Africa it is known as karakan and in India it is ragi and in Kenya it is popularly known as wimbi. The crop is propagated by use of seeds.

2.2 General Uses and Nutritional Value of Finger Millet Grains

The uses of finger millet in Africa include the making of porridge and "Ugali or Sima or Saza", bread and other various products that are relished for their flavor and aroma (Oduori, 2005). It is used to make traditional beer because of its amylase enzyme which

readily converts starch to sugar due to its "saccharifying" power and is only second to barley, the world's premier beer grain in malting qualities.

The straws make good fodder and contain up to 61% total digestible nutrients - better than that of pearl millet, wheat, or sorghum. When sold, it fetches cash for the family and plays a special role in ceremonies like weddings and paying of bride price (Oduori, 2005) as well as attracting other high traditional values (Obilana *et al.*, 2002). It is worthwhile to note that a plant's seed is not only an organ of propagation and dispersal but it is also a major plant tissue harvested by humankind for food (Shewry *et al.,* 1995). Finger millet's nutritional status is appreciably high (Sumathi *et al.*, 2005). It is comparable or even superior to major cereals in respect of protective nutrient content (Oryokot, 2001; Das and Misra, 2010).

When fermented (sprouted seeds), it is nutritious and is recommended particularly for infants, invalids and the elderly persons (Oduori, 2005). Fermented composite beverages of finger millet and milk are popular, nutritious, traditional foods in many parts of Zimbabwe (Mugocha *et al.*, 2000). Fermented flour when dried can stay for a long periods because of non-hygroscopic qualities and therefore can be a sure way of safeguarding food (Okoth *et al.*, 2000).

Among other components of nutritional value contained in finger millet grains is folic acid. Babies need folic acid for good development of the brain and nervous system as well as proper fusing of the bones. This natural source of folic acid has an advantage in the sense that so far no toxicity of folate can arise since the concentration in natural foods is low (Scott *et al.*, 2000).

Finger millet is also rich in a variety of micronutrients like calcium, iron (Table 2) and vitamins which enhance strong bone formation and the immune system by fighting

diseases and infections like diarrhea, acute respiratory infections, malaria and tuberculosis that are major causes of child mortality in developing countries (ACC/SCN, 2004).

Table 2: Nutrient content of various millets with comparison to rice and wheat

Crop\Nutrient	Protein(g)	Fiber(g)	Minerals(g)	Iron(mg)	Calcium(mg)
Barnyarn millet	11.2	10.1	4.4	15.2	11
Finger millet	7.3	3.6	2.7	3.9	344
Foxtail millet	12.3	8	3.3	2.8	31
Kodo millet	8.3	9	2.6	0.5	27
Little millet	7.7	7.6	1.5	9.3	17
Proso millet	12.5	2.2	1.9	0.8	14
Rice	6.8	0.2	0.6	0.7	10
Wheat	11.8	1.2	1.5	5.3	41

Source: Millet Network of India, http://www.milletindia.org [23/11/2013]

Lakshmi and Sumathi, (2004) demonstrated that consumption of finger millet based diets resulted in significantly lower plasma glucose levels due to the higher fiber content of finger millet and also the presence of anti- nutritional factors in whole finger millet flour, which are known to reduce starch digestibility and absorption

Its slow digestion indicates steady flow of blood sugar levels after a finger millet diet thereby reacting as a safer food and can therefore be recommended as popular food among diabetic patients. There are variations, however, in the nutrient content status in the grains and/or seeds of finger millet in different provinces of Kenya (Sehmi, 1993).

2.3 Current Research and Status of Finger Millet Seeds in Kenya

Many traditional food crops like millet, sorghum, sweet potatoes, indigenous vegetables, mushrooms and wild fruits are now associated with poverty and backwardness and are notably disregarded in the agricultural development agenda even though they show significant potential in enhancing nutrient security among poor families in developing countries (Gari, 2004).

Finger millet ranks fourth in importance among millets in the world after sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and foxtail millet (*Setaria italica*) (Upadhyaya *et al*., 2007). Despite its importance, finger millet is grossly neglected both scientifically and internationally in terms of research, compared to the research on other cereals like wheat, rice, and maize as most of the world has never heard of it, and even many countries that grow it have left it to languish in the limbo of a "poor person's crop "(Oduori, 2005).

The Consultative Group on International Agricultural Research (CGIAR) investment research in millet in 1997 was approximately 7 million US dollars representing about 2% of the total CGIAR commodity investment. Breeding efforts in finger millet have been very limited hence genetic knowledge and resources in the crop is scarce (Dida *et al.*, 2006). Moreover, there is a general lack of information on qualities of millet seeds in Eastern African region as the crop is primarily grown by smallholder farmers and mainly consumed at the farms (Olav *et al.*, 1998).

In Kenya, there have been local collections and international acquisitions of finger millet germplasm. KARI scientists are currently multiplying seeds bred at its Kakamega Regional Research Centre. The seed varieties so far released include P224 and KAT/FM-1 but their commercial production for the seed was limited (Kute *et al.*, 2000). The grain

is largely produced by small-scale farmers for domestic consumption. Millet is mainly produced in Nyanza, Eastern, Rift Valley and Western provinces of Kenya, as illustrated in the table

Table 3: Production of finger millet grains in Kenya (metric tons).

Province	Production in Metric Tons	
	2002	2003
Central	44	34
Nyanza	12973	12139
Western	11500	8341
Coast	398	70
Eastern	45211	33601
Rift Valley	6413	9843
Total	76539	64023

Source: *Ministry of Agriculture, 2004* In: Grain Production in Kenya, EPZ, 2005

In yield trials, yields between 1000 – 4000 kg ha-1 have been observed however the yields of the crop are low across African producing countries due to a range of reasons, but mainly less research input. With increased research input in production, processing and utilization, the crop holds a lot of potential in productivity, commerce and industry in Africa (Oduori, 2005). In its genetic development as a crop, finger millet is about where wheat was in the 1890s (NRC, 1996). Since the 1890s, average yields of wheat have risen from 500 $kgha^{-1}$ to over 4,000 $kgha^{-1}$.

Finger millet's yield could rise similarly and much more quickly because of the facts that it is a C4 compared to wheat, a C3 plant and advanced breeding methodologies developed on other crops already exist (Oduori, 2005). Crossing in finger millet has long been impeded by its highly self –pollinating nature of the crop and the small flower size has made hand emasculation difficult (Dida *et al.,* 2006).

2.4 Earnings from Finger Millet in Kenya

Millet production in Kenya is classified into three categories (MOA, 2007a) namely; Finger, pearl and proso millet. Kenya largely produces the finger millet. Production in 2003 was 64,023 tones, which met the domestic requirements. Millet is often used as a substitute to maize in case of the latter's' failure (EPZ, 2005)

2.5 Seed Supply System

Kenyan seed system is governed by the Seed and Planting Materials Act (CAP 326). The Kenya Plant Health Inspectorate Services (KEPHIS) is mandated by the Act to regulate the production of certified seed in order to ensure that high quality seed standards are maintained (Ayieko and Tschirley, 2006). Reforms are under way for the sustainable development of seed industry in order to avail high quality seeds and planting materials to farmers through National Seed Policy (MOA, 2007a). This is in line with evolution of the seed industry worldwide in the past three decades (Bernard, 2007).

KAM, (2006) on their press release stated that seed are widely distributed in national and international trade, and it has also been mentioned in breeding programmes (Abdulsalaam and Shenge, 2011). Seed supply systems can be grouped into traditional (informal) and modern (formal) systems.

2.5.1 The Informal System

Over 90% of the seed crops in developing countries are still planted with farmers' farm-saved seeds(FAO, 2009).The majority of farmers in Africa mainly get their seeds from this sector which does not receive support by the governments (Wekundah, 2012). In this system, seed sources can be classified as: own seed (seed selected by the farmer from his own harvested field); seed acquired from relatives or near neighborhood; introduced seed

(seed acquired outside the village); seed acquired from the traditional market (seed origin is unknown) and seed acquired from breeders (Didier and Mahamadou, 1999).

Approximately four-fifths (78%) of all seed used in Kenya comes from the informal sector (Ayieko and Tschirley, 2006) where farm-saved seed is the key source for and could only resort to off- farm sources in cases of drought ,poverty or food insecurity (Wanyera and Akol, 2008).Typically, farmers designate some of their harvest as "seed," treat and store it separately from grain, and only sow from this the following season (McGuire, 2007) but the quality has not been verified (Ednar *et al*., 2006**)**.

The quality or planting value of the farmer-own saved seeds (FOSS) varies from farmer to farmer as they follow no defined technique in seed handling and preparation for storage or sowing and consequently seeds are not tested before sowing (Kabeere, 2001). A study conducted in Kenya concerning seed storage compounds in finger millet grains and/or seeds revealed that the said compounds vary substantially in different provinces and even among the districts within a province in Kenya (Sehmi, 1993).This implies that seeds taken from one part of the country may perform differently from the other. In this way variety maintenance as an important aspect of seed supply is not forthcoming (Almekinders and Louwaars, 1999).

While the formal seed system is an important source of high quality certified seed, it is not able to meet the farmers' demand. Majority of farmers therefore rely on the informal seed system for seed and planting material for most agricultural commodities, and often recycle seed that has been exhausted through generations of cultivation and the results have been low yields (Ayieko and Tschirley, 2006**).** This informal seed supply system is however constrained by a number of factors such as drought, infrastructure, hygiene, and quality of the seeds as well as lack of credit facilities (Larinde, 1998).

2.5.2 The Formal System

In the formal seed system, a part or all of the seed is bought from seed producers. This system is characterized by a high degree of specialization. The seeds are produced with ample use of hired labor as well as inputs such as fertilizers and pesticides with entire seed value chains guided by defined methodologies which are also internationally standardized, and backed by national legislation (Odame and Muange, 2010).

Formal seed systems in Africa have not been able to meet farmers' needs (Tripp, 1997; Opole, 2005). Combinations of both systems exist as well; some farmers use the informal and formal systems on their farm, either or not for different crops. The effectiveness of the linkages between research in variety development, on-farm demonstrations and seed delivery systems hold the key to the success of the coexistence especially in terms of the impact that will be created at the farm level of the smallholders (Kugbei and Bishaw, 2002). Some studies have indicated that farmers demand for the seeds of improved varieties could be elicited with availability of seeds (Daniel and Adetumbi, 2004).

2.6 Quality Aspects of the Seed

2.6.1 Moisture Content

The ideal moisture content regime for most seed storage is between 5% and 14%.Low seed moisture content is a pre-requisite for long-term storage, and is the most important factor affecting longevity. However, seeds lose viability and vigor during processing and storage mainly because of high seed moisture content (seed moisture greater than 18%)(McCormack, 2004). This observation does not apply to recalcitrant seeds where desiccation has been found to drastically affect seed quality (McDonald *et al*., 2011).Very low moisture content can be achieved through air drying systems. However, excessively

high drying air temperatures can have deleterious effect on seed quality(Hill and Johnstone, 1985).

2.6.2 Seed Purity

A Seed is purchased with an understanding that the species and variety is the principal constituent in a seed lot. The genetic purity of any commercial agricultural product propagated by seeds begins with the purity of the seed (Bradford, 2006). In reality during harvesting and cleaning of the seed, other types of seed and materials are present hence it is not possible to get 100% pure seed. The major source of contamination in the field is volunteer crop and failure to adhere to prescribed isolation distance. It is only the type and level contamination of these other components that can significantly influence the value of the seed. Thus seed purity is therefore based on the physical determination of components present measured in percentages by weight. The higher the percentage of the pure seed the better the quality of the seed lot.

2.6.3 Seed Germination

Germination may be defined as the resumption of active growth by the embryo culminating in the development of young plant from a seed, also technically expressed as the uptake of water by the seed and ending with the start of elongation by embryonic axis, usually the radicle (Bewley and Black, 1994). The proportion of the seeds in a seed lot that give forth to such young plants is critical.

High-temperature stress before developing seeds reach physiological maturity (PM) reduces germination by inhibiting the ability of the plant to supply assimilates necessary to synthesize the storage compounds required for germination (Hampton *et al*., 2011). It is therefore possible that germination of the seed can be affected before the seed is fully developed. This proportion constitutes the percent germination and can be used to

determine the planting value of a seed lot, its storability as well as information on its marketability. Germination of small seeds can be enhanced by short exposure of seeds to heat through microwaving (30 seconds) however excess heat or prolonging exposure period reduces germination (McCormack, 2004). In Kenya, finger millet seeds that have germination percentage over 70% are acceptable.

2.6.4 Seed Health

Seeds are highly effective means for disseminating plant pathogens over long distances due to their high mobility. In the informal sector, farmers plant their own seed which carry out diseases from one season to the next (Ednar *et al*., 2006) because seed health is not assured.

Plate 1: Blast *(Pyricularia grisea)* on millet. (Source: ICISAT, 2009)

Blast caused by the fungus *Pyricularia grisea* (a close relative of rice blast) is the most serious disease (plate 1) of finger millet (National Research Council (NRC, 1996; CGIAR, 2001). This is a seed borne disease (Pande *et al.*, 1994) and that it affects all aerial parts of the plants at all stages from seedlings to grain formation stage (Kumar *et al.*, 2006).

Shetty *et al*., (1985) showed that planting seeds of finger millet infested by *P. grisea* clearly resulted in epidemics in small plots in the field and showed that the amount of disease was correlated to the amount of blast found on seeds. Farmers have the knowledge of the disease but do not know the mode of transmission and the only way to avoid is to select seeds from healthy looking panicles (Sreenivasaprasad *et al*., 2004) and the detection of the disease through the grains and/or seeds is therefore not forthcoming.

Other disease causing organisms of concern includes *Biloparis setariae, Fusarium moniliforme,* and *Phomasp*. The crop has few pests, for instance shoot fly and stem borers, of which both can be controlled by insecticides. Birds are also a pest, especially, the notorious *Quelea quelea* and other small grain feeding birds.

2.6.5 Seed Vigor

Seeds of high quality are said to be of high vigor. The specific time to select the seed while in the field greatly affect the vigor. Seed vigor is influenced by time of harvest of the seeds and position of the seed on the inflorescence, seed coat, membrane permeability as well as moisture content (McDonald and Copeland, 1997; McDonald, 1999). Fortunately finger millet seeds are found almost at the same position in the inflorescence.

Seed crops should be harvested when quality traits of the seeds are maximal though specific times vary with the crops species (Demir *et al.*, 2002).Seed physiological maturity (PM) also referred to as maximum seed dry mass has been described as a measure of maximum seed quality (TeKrony and Egli, 1997). Springer *et al*., 2001 stated that seed size is significantly correlated to germination of most species of grass family. Lightweight seeds typically have less energy available for germination, and the resulting seedlings are usually smaller and less vigorous. The low vigor seeds are slower to germinate and less tolerant of stressful conditions at planting (Spears, 2004).

2.7 Production Techniques Affecting Quality of Finger Millet Seeds

Seed supply, storage and conservation require techniques that are stricter than those required for consumption grains. The techniques and traditional products that intervene in seed management must guarantee the plant germinating power and safe growth. Seed production techniques that may affect seed quality are varied and range from selection, processing and storage (Elias and Copeland, 1994).

2.7.1 Seed Selection

Selection is an important aspect of seed production. This is done to: improve seed vigor by selecting well-developed plants and plump seeds only (Physiological and analytical quality), reduce disease incidence by discarding obviously diseased plants or seeds (sanitary quality), maintain the genetic quality of the variety (varietal identity), continually adapt the variety to changing growing conditions; and obtain better varieties (Almekinders and Louwaars, 1999).

Farmers generally select in their fields and in their seed stores, thereby preventing natural selection from introducing weedy characteristics into the crop, such as shattering seeds, weedy plant architecture and other characteristics that may be positive for plant survival, but negative for crop production. There are different selection methods, which can be employed during different phases of seed production. Seed selection before harvesting gives the farmer the possibility for a higher degree of seed management and a wider range of options for crop improvement but only to the extent that this is done on the basis of physical attributes of seed, and not with an intention to select for specific genetic traits.

The stage of crop growth at which a distinction is made between what will ultimately end up as food grain and what will be used for seed is an important indicator in this respect. Seed crops should be harvested when quality traits of the seed are maximal (Demir *et al.*,

2002). Seed quality is normally higher at physiological maturity (PM) (Khatun *et al.*, 2010; Olasoji *et al.*, 2012) however this is not the case for all seeds (Siddique and wright, 2003). At PM the seed attains maximum dry weight but if harvested before this, it will have less weight and will shrivel upon drying. During the maturation process, the ripening panicles change color (see plate 2) from green, to yellow-green, to yellow, to light brown, to a darker brown, or dark gray (McCormack, 2004).

Plate 2: Panicles of finger millet at the stage of harvest maturity.
(Source: Author, 2012)

The second method of Selection is done after harvesting, but before threshing and storage. This is a very common method in other crops such as maize and sorghum, where the best-looking ears and heads are kept aside for use as seeds (see plate 3). The third method is selecting healthy and 'true-to-type' seeds from the stored grain, i.e. seed that resembles those of the mother crop and does not show obvious disease symptoms and which could otherwise serve as food.

Plate 3: Seed selection after harvesting. (Source: Author, 2012)

2.7.2 Seed Processing

Seed processing refers to all the steps necessary to prepare harvested seed for market. It is a critical factor that seriously affects the quality. After harvest, seeds are threshed to remove the seed from the surrounding plant material and a period of air-drying is important before seeds are threshed. Threshing of finger millet seeds from the husks sometimes involves use of mortar and pestle or beating the harvest using sticks. Depending on moisture content, mechanical damage to the seeds can occur resulting in deterioration of vital embryonic tissues and that any break in the seed coat affords an excellent opportunity for fungi to enter the seed, and either kill it, or weaken the seedling that will be produced from it. Some caution should therefore be observed to prevent seed damage as it reduces seed germination and vigor (Maryam and Oskouie, 2011). Part of the seed processing would involve spreading out the seeds in thin material until it is dry; otherwise, mold, decay, and heat would cause damage to the seeds (McCormack, 2004).

Processing of finger millet after harvesting has been found to have profound effect in the germination. Seeds threshed from soaked heads have been found to have higher

germination than those from dry heads (Msuya, 2004) due to the shortening of the lag phase in germination (Sabongari and Aliero, 2004). It has also been observed that threshed grains exhibited higher degrees of germination compared with non-threshed grains. This is due to presence of lemma and palea (Hilu and Wet, 1980).

2.7.3 Seed Storage

The primary purpose of storing seeds is to save seed from one season to the next, but farmers and seed companies often find it useful or necessary to store seeds for at least two to three years, and sometimes longer. It is an important aspect of any sound seed management programme (Malik and Shamet, 2009). The informal seed supply system does not give preference to seed storage to the rest of harvested grain stored unless the grain was initially produced as seed. The seeds for planting are not kept apart from the rest of the grain produced in the informal system (Fatima, 1999) and so is the case of finger millet seeds. In some instances grains that remain after consumption as food, serve as seeds and thus quality is compromised. What is even worse is the fact that ideal storage conditions are unobtainable under conditions prevailing in tropical countries (Vanek and Hobbeg, 1992; Govender *et al.,* 2007; Singh *et al.,* 2008).

Seeds lose viability and vigor during storage mainly because of high seed moisture content which increases the respiration rate of seeds, and in turn raises seed temperature. This encourages mold growth thus damaging the seeds either slowly or quickly and insects such as weevils can breed causing rapid destruction of seeds in a short period of time (McCormack, 2004).The magnitude of storage losses depend on the type of storage structure, storage environment and biotic factors which in turn influence rate of seed deterioration (Mlambo *et al*., 1992). Traditional storage methods are not efficient though comparatively cheap and accessible to farmers (Kabeere, 2001; Okiror *et al.,* 2001; Thamaga-Chitja *et al*., 2004). Some of the traditional seed storage methods have been

found to improve seed germination and vigor. Seeds storage over fire and smoke showed higher germination and vigor than non-smoked seeds (Modi, 2004). The smoke contains butenolide substances also known as karrikinolides which are now recognized as potential new plant growth regulators (Smith, 2006; Kulkarni *et al*., 2011).

2.7.4 Seed Yield in Finger Millet

The numbers of grains per head per unit land area and individual weight of the grains that reach maturity define the yield in cereals (Lucas and Maria, 2001). The reduced seed number in cereals is influenced by insufficient pollination, sexual selection of male and female gametophytes and resource limitation of maternal plant (Douglas and Ralph, 2001). Significant correlations have been found between seed yield and vegetative as well as reproductive characters in finger millet and that grain yield is influenced by days to emergence, days to 50% flowering, finger length, finger width, and weight of grains of the main ear head (Bendale *et al*., 2002) however delays at harvest maturity of any seed crop could possibly encourage conditions that enhance deterioration (Wambugu, 2006) and consequently lead to low yield.

2.8 Seed Quality Tests

One of the greatest hazards in agriculture is sowing seed that has no capacity to produce an abundant crop of the required cultivar (ISTA, 1993). Seed testing has been developed to minimize the risks by assessing the quality of the seed before it is sown. It is the cornerstone of all other seed technologies and the means by which the viability and all the physical factors that regulate the use and maintenance of seeds are measured. It is also imperative that the seeds used for raising a crop should be of known purity, appropriate class and invariably obtained from an official agency (Agrawal, 1980).

Quality of seed lots is generally expressed by germination capacity. Environmental conditions and those of growth of the mother plant influence deterioration of seeds due to physiological, mechanical or parasitic disorders. Finger millet seeds are in the category of small grain cereals and that genetic composition of a small grain variety dictates heading date, disease and insect resistance, stand ability, quality appearance as well as protein composition, and many other characteristics (Brocke *et al*., 2006).

Planting of seeds with high level of viability, physical purity and freedom from noxious weed seeds and diseases increases the probability of successful establishment of a uniform and vigorous stand that is of paramount importance to the successful production of most crops. Seeds should be selected randomly so that they can be ascertaining for their quality status is necessary (Kruse, 2007). Variation in vigor is perhaps the most ubiquitous and it is virtually inevitable that even among seeds that are all viable, there will be differences in their rates of germination, in their sensitivity to environmental stresses and in their susceptibility to pathogens (Bradford, 2007). It is therefore necessary to employ a number of tests for a given seed lot to ascertain particular seed attributes. Germination test is one of the tests as it would indicate the ability of the seed to develop into a normal plant under favorable conditions in the soil (ISTA, 2004).

Seed vigor tests have also been used to detect differences in potential seed performance. Finger millet seeds are in the category of small grain cereals and proposed vigor tests would be accelerated ageing test (AA), electrical conductivity (EC), as well as germination index (GI) (Wang *et al*., 2004; Khan *et al*., 2007).

2.8.1 Critical Review of the Literature

Formal seed systems in Africa have not been able to meet farmers' needs and have shown little interest in non-hybrid crops (Tripp, 1997).It is interesting to note that majority of

farmers rely on the informal seed system for seed as planting material for most agricultural commodities and often recycle seed (Ayieko and Tschirley, 2006**)** though it has been observed that farmers demand for certified seeds was high if the said seeds were provided (Daniel and Adumbi, 2004).It is however acknowledged that the commercial production of certified seeds of finger millet in Kenya is limited (Kute *et al*., 2000). Thus most farmers in Kenya use seeds of finger millet in which there have been no stringent requirements followed in their production .Seed production practices must guarantee germinating power and safe growth of the resultant seedling. Seed selection, processing, and storage have been seen to affect the quality in one way or the other hence the need to establish their effects. Most of finger millet seeds in Kenya and Soin division in particular come from informal sector hence there is need for various stakeholders to be equipped with knowledge and skills of producing the seeds and by extension enhance the development of a Seed system that encourages wider use of quality seeds at all levels to tackle poverty and food security (Ayieko and Tschirley, 2006).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site Description of Study Area

Soin division covers an area of 300km^2 and lies between the longitudes 35 02^o E and 35 40^o E and between the equator and latitude 0 23^o S (Annonym., 2006). It is one of the divisions in Kericho County where the study was carried out. The division is characterized by undulating topography with the overall land sloping to relatively flat lowland to the west and hence drainage was in that direction. It has six locations namely; Soliat, Koitaburot, Kaitui, Kapsorok, Kapsegut and Soin. There were 5800 small scale farmers of which 1100 were directly involved in the growing of finger millet. It is one of the marginal areas in terms crop production.

The altitude ranges from1000 m to 1500m and the rainfall was between 750-1200mm *p.a* with temperature range of 20 -30^{o}C. The dominant soils were mainly clay loams (Jaetzold and Schmidt, 1982). The arable land was 27,460 ha and the average farm size was 2.5 ha. The main cash crop was sugar cane and food crops were maize, sorghum, beans, cassava and finger millet.

The map of the research site is in Appendix III at the back of this document. Soin division is currently constituted by two county assemblies namely Soliat and Soin county assemblies.

3.2 Survey on Seed Situation in Soin Division

3.2.1 Sampling Method

A reconnaissance survey was conducted in the study area purposefully to gather information from the ground about the intended research. This was to enable the researcher to make contacts with the agricultural officers and subsequently to design modalities of carrying out the survey.

The sample size of 240 farmers growing finger millet was selected for the study using the formula adopted from Israel (2009).

$$n_{0} = \frac{z^2 qp}{e^2}$$

Where;

$\mathbf{n_0}$ = sample size

z^2 = 1.96, abscissa of the normal curve that cuts off an area at desired confidence level of 95% and is obtained from statistic table

p = (1100/5800) proportion of finger millet farmers in the population

q= 1-p

e= (0.05) desired level of precision

$$n_{0} = \frac{1.96^2 \times 0.19 \times 0.81}{0.05^2}$$

n_0= 236≈ 240

3.2.3 Administration of Questionnaires

With the initial sample size of 240 farmers, each of the locations had been slotted 40 farmers. In each location, snowballing technique was used to get the farmers. In this technique each farmer visited was asked to direct the researcher to other farmers who grow finger millet.

Questionnaires were administered that had information such as location of the farmer residence, education level and the level of experience in finger millet farming, sources of the finger millet seed, seed practices (Seed selection, seed processing, seed storage and treatment). Besides that information, samples of finger millet were collected from the farmers. Each of the farmers who gave a sample of seed was asked to say how the seed was produced on the basis of selection, processing and storage .In each case a tag was put

on a sample to represent a process used. The researcher relied on the information regarding the seed production techniques that were used by the farmers and consequently grouped the seed samples into three selection methods, three processing methods and three storage methods. They were then sealed in water proof paper bags and taken by road to University of Eldoret seed laboratory for analysis. A sample was obtained from the seed company to act as a control.

3.3 Seed Quality Tests

A representative sample from each of the nine categories of seeds was picked for analysis of each of the following seed attributes; moisture content, analytical purity, germination test, vigor, and seed health. The samples of finger millet seeds obtained were classified based on the seed selection, seed processing and seed storage methods. These samples were taken through some laboratory procedures to determine the seed quality features.

The seed quality characteristic that were looked into were, moisture content, analytical purity of the seeds,seed germination, electrical conductivity of the fresh seeds, Electrical conductivity for the aged seeds, Seed health, seed germination of the aged seeds, Germination index for fresh seeds, and Germination index for aged seeds. The objective of undertaking laboratory procedures was to help determine the best seed selection, seed processing and storage methods.

3.3.1 Analysis of Moisture Content

Moisture content is of one the most important factors influencing seed viability and longevity. This was the first test done as soon as the seed arrived at the laboratory; the seeds were subjected to high constant temperature oven method (130-133^{o}C) for 2 hr wrapped in aluminum foil.

The sample was weighed before heating and weighed after and the weight loss was assumed to be the moisture that was withdrawn from the seeds by heating and was quantified by determining the amount of loss in weight to the original material. Moisture content of the seed sample was the loss in weight when it was dried and expressed as a percentage of weight of the original sample (ISTA, 2004). The results were recorded in two replicates and presented as shown in the formula.

$$\%\ Moisture = \frac{m_2 - m_1}{m_1} \times 100$$

Where m_1 = Initial weight before heating

m_2=Final weight after heating

3.3.2 Analytical Purity Analysis

The objective of analytical purity test was to determine the mechanical quality of the sample and the percentage, by weight, of each of the component and by inference the composition of the seed i.e. pure seed, seed of other species and inert matter. The sample weighing 6g (ISTA, 2004), which had gone through basic cleaning, was placed onto smooth surface and divided into the above three portions. Each fraction was weighed and reported as a percentage of the total weight. These were then reported as; Percent pure seed, other crop seed, and inert matter. The quality was considered high if purity percentage was above 99%.

3.3.3 Seed Germination Test

This test determined the maximum germination potential of a seed lot (ISTA, 2004). This test can be used to compare the quality of different lots and also estimate the field planting value under favorable conditions. 200 seeds replicated four times were plated on top of moistened paper substrate and incubated at 20-30^{o}C (ISTA, 2004).

A solution of 0.2% $KNO_3$was added to break dormancy. The first count was made after 4 days and second count after 8 days.

3.3.4 Vigor Tests

These tests were conducted in order to establish seed vigor. Seed vigor is the sum total of all those properties of the seed that determine the level of activity and performance of non-dormant seed or seed lot during germination and seedling emergence (Perry, 1978). The rationale behind was that a vigorous seed lot was likely to succeed under wide variety of field condition whereas a non-vigorous seed lot was unlikely to produce a satisfactory stand under field conditions. Vigor test was therefore meant to reliably predict the stand producing potential of a seed lot.

3.3.4.1 Germination Index (GI)

In this test the speed of germination is seen as an indicator of vigor. The faster a seed lot completes the germination or reaches its peak the vigorous it was said to be. Daily counting of the germinated seeds from the time the first germination was noted i.e. 4^{th}day to the 8^{th} day was recorded. This was done concurrently with seed germination test and using the formula below, the germination index, GI, was determined for a seed sample

$$GI = \sum(Gt/Tt)$$

Where

Gt=Germination percentage at tth day

Tt =Day of germination test.

The higher value shows that the quality was good and vice versa.

3.3.4.2 Accelerated Aging Test

This test was conducted with stress of high temperature and moisture as suggested by Hampton and TeKrony (1995) and proposed strongly by Khan *et al.,* (2007). Two gram seed samples from each for each seed lot was placed on a wire mesh screen and suspended over 40ml water inside a plastic accelerated aging box. The boxes were kept at 41^{o}C and near 100% relative humidity for 72 h. After aging, the seeds were removed from the ageing box, germinated at 20-30^{o}C and evaluated after 4 and 8days. The seeds that showed high germination percentage were considered to be of high quality.

3.3.4.3 Electrical Conductivity Test (EC)

The measurement of electrical conductivity of leachates provided an assessment of the extent of electrolyte leakage from the seeds and by inference the membrane integrity. Seed lots with high electrolyte leakage had high leachate conductivity and were considered as having low vigor while those with low leakage (low conductivity) were considered high vigor. This method adopted Wang *et al*., 2004 and Khan *et al.*, 2007. Three replicates were drawn from each sample and weighed to 0.5g each. Then soaked in 100 mL distilled water in a 150-mL flask stirred, covered, and held at 20±2^{o}C for 20-24 h. Hard seeds in each replicate were removed, surface dried and weighed. The weight obtained was subtracted from the initial weight in each replicate. The EC was then calculated as;

$$EC = \frac{conductivity\ reading\ (\mu scm^{-1}) - background\ reading}{weight\ (g)\ of\ replicate}$$

$$EC = \mu scm^{-1} g^{-1}$$

3.3.5 Seed Health Test

This test was carried out to determine the health status of a seed sample and by inference that of the seed lot (ISTA, 2004). Physical examination of the seeds with a view to identifying the color of the seed coat would play an indicative role in this test. For a Grey or black discolored have higher level of infection by *Pyricularia grisea* than apparently healthy normal brown seeds (Pande *et al*., 1994).Confirmation test was done to detect the presence of fungus using blotter method. Four hundred seeds were plated in replicates of 25 seeds per Petri dish and incubated at 20 ^{o}C for 24h, then deep frozen for 24h thereafter maintained at 20 ^{o}C for 5 days in cycles of 12 h darkness and 12h daylight. The seeds that showed infection were counted per replicate in all the samples.

3.4 Data Collection and Statistical Analysis

The questionnaires were used to collect pertinent information from farmers growing finger millet and were coded for ease of analysis. Findings from laboratory experiments were recorded in replicates and analysis was done using SPSS version 16. Categorical variables were summarized as frequencies (percentage) while the continuous variables were summarized as mean (SD). Association between the primary explanatory variables (selection methods, storage methods and the processing methods) and the outcome (moisture content, germination percentage, electrical conductivity of the fresh seeds, accelerated ageing, seed health, and germination index for fresh seeds and percentage purity) was assessed.

To answer the question a one way analysis of variance (ANOVA) was performed to compare the means. In cases where the normality assumptions were violated the non-parametric comparison procedure called the Kruskal-Wallis test was performed. The one way analysis of variance (ANOVA) tests and the Kruskal -Wallis tests were the

parametric and nonparametric methods, respectively, for testing for the existence of statistically significant differences in the outcome across the four groups of seed selection methods or seed processing methods or seed storage methods. If the ANOVA test or Kruskal- Wallis test was statistically significant (i.e. $p<0.05$) then they are followed by Bonferroni or Wilcoxon rank sum test, respectively. The Bonferroni p-value is adjusted for the number of groups by dividing the nominal p-value (0.05) by the number of groups which was four in this case. Therefore the multiple comparison tests was statistically significant if the p-value is less than 0.0125 (equal to 0.05/4)

CHAPTER FOUR

RESULTS

4.1 Survey on Seed Situation

Out of the targeted 240 small scale finger millet farmers in Soin division of Kericho district, 177 were reached during the survey. This translated to a response rate of 73.8%. The distribution was even and the mean per location was 16.7%. The number of farmers per location is shown below (Table 4).

Table 4: Number of finger millet farmers in Soin Division

Location	Frequency	Percentage
Soliat	28	15.8
Koitaburot	30	16.9
Kaitui	31	17.5
Kapsorok	25	14.1
Kapsegut	31	17.5
Soin	32	18.1
Total	177	100.0

4.1.2 Level of Education of the finger millet farmers

It was noted that 14% of the farmers never attended school, 51% had at most primary level of education while 35% had at least secondary level of education (Table 5). From the findings, it is evident that majority (65%) of the finger millet farmers have elementary formal education and consequently low scientific knowledge on seed qualities. The inadequate knowledge impacts negatively on the status of the seed to be produced and used. The adoption of any new technology to a large extend is determined by the level of awareness of the farmers. This proposition is supported by earlier studies by Daniel and

Adetumbi (2004) that farmers demand for the seeds of improved varieties could be elicited with informed knowledge.

Table 5. Level of education of the finger millet farmers

Education level	Percent
Never attended school	13.6
Primary education	51.4
Secondary education	20.3
College	14.7
Total	100.0

4.1.3 Experience in the Growing of Finger Millet

The farmer's experience in finger millet farming was sought and the results were as presented in Figure 3. There was a slightly higher number of farmers with experience in the growing of finger millet between one to five years then dropped and then gradually picked up from six years' experience onwards. From this figure it can be seen that there was a general trend that the numbers of farmers having vast experience in this field increased with rise in the years. This implied that the growing of finger millet was popular with persons over forty years old if one became a farmer at the age of eighteen in the Kenyan context. Finger millet is also labor intensive and a farmer can venture into the growing of the crop and abandons it immediately within one to five years. It could also be postulated that young farmers prefer other crops to finger millet. Sugar cane is the most popular cash crop with better economic returns the hence the majority of the young farmers would go for such ventures. There is also an aspect of attitude in some countries as was observed by Oduori (2005) where the crop is seen as a "poor person's crop".There

is also an aspect of attitude in some countries as was observed by Oduori (2005) where the crop is seen as a "poor person's crop".

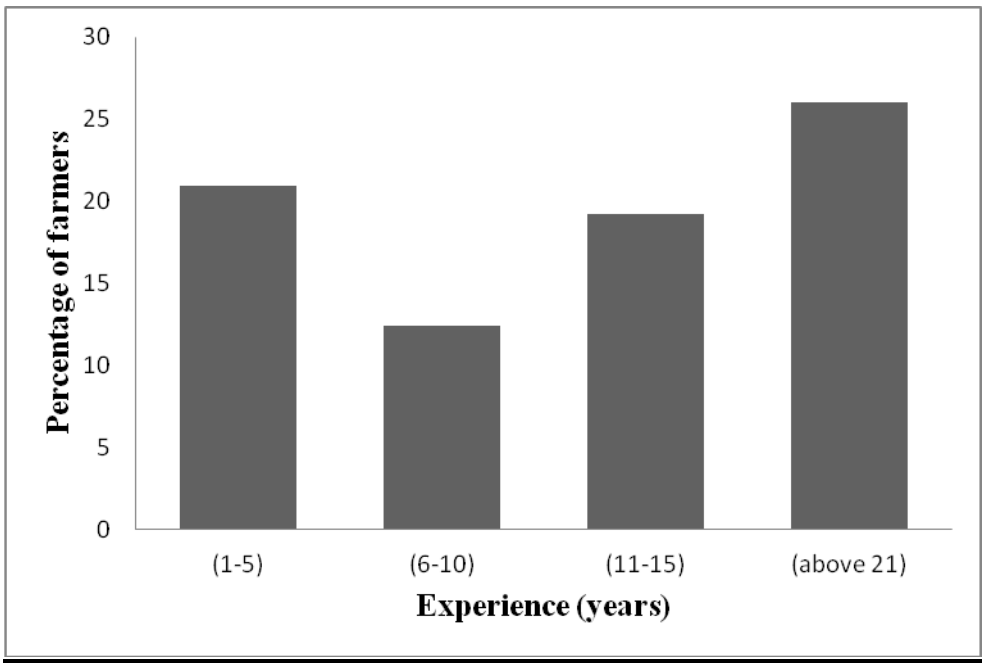

Figure 3. Farmers' experiences in years in the growing of finger millet

4.1.4 Farmers' Sources of Finger Millet Seeds

It was observed that farmers obtained finger millet seeds from different sources. Of the 177 farmers only 12% obtained their seeds for planting from the seed company in addition to other sources.Farmers obtaining seeds from the seed company reported that the seeds were disease resistant 23%, drought resistant 4%, early maturing 55%, and high yielding 18%.Apart from the seed company, farmers obtained seeds from their own savings 40%, other farmers 35% and from the market via purchasing 25%. The distribution of the farmers obtaining seeds from the other sources by location is as shown in Table 6. The Fisher's test of association between the other sources of finger millet seeds for the farmers and the location of the farmers in Soin division was statistically

non-significant (p=0.13) implying that there is no association between the source of the seeds and the location of the farmer.

Table 6.Sources of seeds planted by farmers in Soin Division.

Location of Finger Millet Farmer	Sources of finger millet seeds				
	Seed company	Own saved seeds	Other farmers	Market	Total
Soliat	3	7	14	7	28
Koitaburot	3	9	15	6	30
Kaitui	4	12	10	9	31
Kapsorok	3	13	6	6	25
Kapsegut	5	17	9	5	31
Soin	4	13	7	12	32
Total	22	71	61	45	177

4.1.5 Method of Seed Selection used by the Farmers

Greater proportion of farmers identified their seeds by assessing and identifying some specific panicles while in their developmental stages in the farm representing71%. This was possible due to long standing experience stretching to over 21years in the growing of the crop. Twenty seven percent selected panicles before the entire harvest was kept in a store; healthy looking panicles were kept aside to serve as seeds. This was a very common method in other crops such as maize and sorghum, where the best-looking ears and heads were kept aside for use as seeds. While the least proportion of farmers 2% got the seeds from the grains meant for food.

Selection of seeds while in the field was done via observation of a number of indicators. These indicators were assessed and the farmers' response showed that 14% identified their seeds once the panicles started changing color, 10% observed the thicknesses and

the firmness of the grains, 6% observed the folding in of the fingers and 70% observed the folding out of the fingers.

4.1.6 Seed Processing

Sixteen percent of the farmers threshed panicles after sun drying while sixty seven percent kept the harvested panicles in the sack for some time before threshing. Those that threshed immediately after harvest were slightly ahead of those who sundried by 2 %. Processing of finger millet after harvesting has been found to have profound effect in the germination as the seeds would have lost most moisture hence can withstand mechanical beating. The farmers in Soin division of Kericho County appear to have this idea from the findings of the study.

4.1.7 Seed Storage

Fifteen percent of farmers stored their seeds in tins. These could either be metallic, plastic or clay pots. Thirty seven percent of them stored their seeds in sacks which were either made of sisal fibers or synthetic material. It was then kept in a crib or some place within the house. While forty six percent of the farmers' stored seeds above fire place. This method was more popular among the farmers in Soin division as one of traditional seed storage methods. The seeds sored in this way have been found to have improved seed germination and vigor. Seeds storage over fire and smoke showed higher germination and vigor than non-smoked seeds (Modi, 2004). The two percent were the non-respond.

4.1.8 Seed Treatment

There were three main methods used for seed treatmnet, namely; ash,chemicals from agro- shop and smoke. A small proportion of the farmers treated their seeds usingdifferent materials namely; ash 13 %, chemicals from agro shop 7% while 1% used smoke to treat their seeds. Those that did not treat their seeds constituted 79%. Figure 4 shows the distribution of the seed treatmet methods among those who treated their seeds.Though the

percentage of the farmers who treated their seeds using smoke was 1%. It can be inferred from methods of storage that this percentage could be higher than this because 46% of them said that they stored the seeds above fire place where smoke is inevitable.

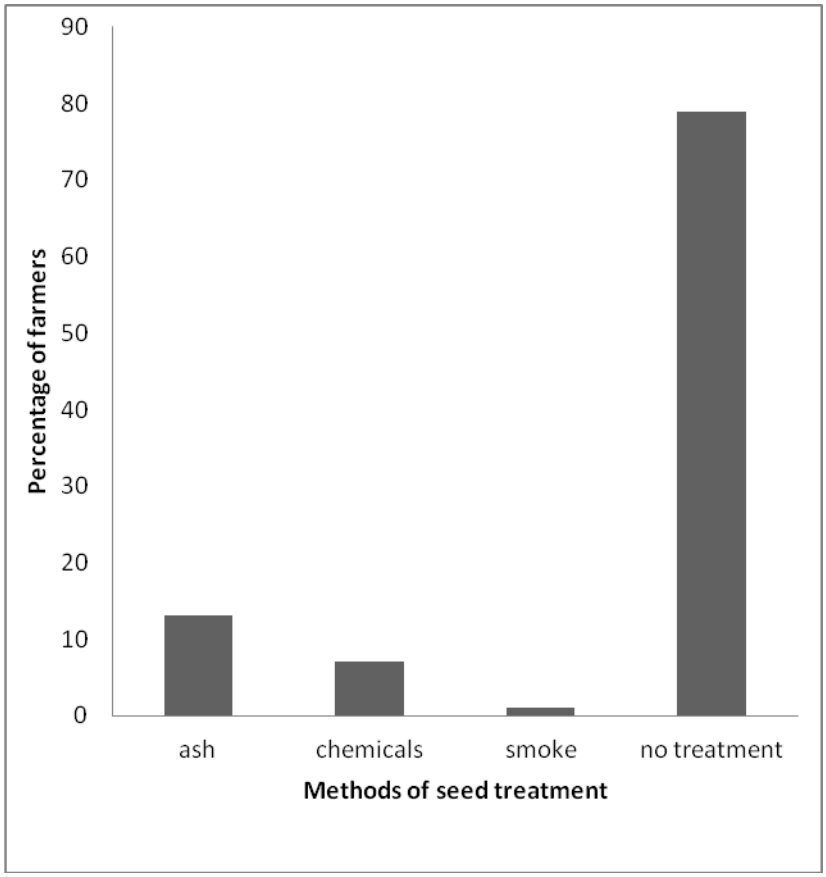

Figure 4.Methods of seed treatment during storage by local farmers

4.2 Testing for Differences among the Seed Selection Methods

4.2.1 The Effects of Selection Methods on Seed Moisture Content

The values for seed moisture content means in percentage among the seed selection methods are shown in the Table 7. The one way ANOVA showed that the differences between the means were not significant (P-value = 0.177). This meant that the selection methods did not affect the moisture content of the seeds. It could also imply that the selection methods had no control of moisture.

Table 7: Percent Seed Moisture content (%MC) of seeds from different sources: G0; seeds selected in the field, G1; seeds selected after the harvest, G2; seeds picked from grains meant for food.

Treatment	% MC
Control	6.8 a
G0	8.1a
G1	6.9a
G2	6.6a

*values with same letters are not different according Bonferroni

The ideal moisture content regime for most seed storage is between 5% and 14%.Low seed moisture content is a pre-requisite for long-term storage, and is the most important factor affecting longevity. All the selection methods used by the farmers gave moisture contents within this regime.

4.2.2 The Quality of Seeds obtained from Different Sources

Table 8: Percent analytical seed purity and germination percentage of seed from different sources. G0; Seeds selected in the field, G1; seeds selected after harvest, G2; seeds picked from grains meant for food.

Treatment	Purity%	Germination%
Control	99.3 a	73a
G0	98.4 b	59b
G1	96.9c	52bc
G2	93.5 d	45c

* Values with same letters are not different according to Bonferroni

The distribution of the outcome variables was skewed thus the comparison of these means was conducted using the Kruskal Wallis test showed that the difference was statistically significant at 5% level of significance. The Wilcoxon rank sum test was then used to establish which of these groups actually had different average purity proportions and the

results showed that all the methods were different from each other. The control was better than the rest of the methods. Table 8 shows that the three selection methods gave seed purity values below 99% (ISTA, 2004). The lowest value of 93% was from the seeds obtained from grains meant for consumption. Two of the selection methods used by the farmers produced purity percentages above allowable limits for the finger millet seeds in Kenya of 95% (Sikinyi, 2010). On germination percentage, the one way analysis of variance (ANOVA) was done to compare the means and the differences were statistically significant at 5% level of significance. To establish which of the methods was different from each other, Bonferroni was performed where it was found that the control was different from seeds selected from the field, seeds after harvest and from seeds obtained from grains meant for food.

There was no significant difference between selections in the field and after harvest and neither was there any difference between after harvest and grains for food. There existed a significant difference between selection in the field and selection from grains meant for food. Selection of the seeds from the field gave higher germination percentage than selection from grains meant for food. This observation showed that the selection of the seeds in the field gave higher purity of the seeds which in turn resulted in higher germination. The germination percentages were however, lower in all the three methods of selection than the acceptable standards in Kenya (Sikinyi, 2010).

4.2.3 The Speed of Germination (GI) of seeds from different source

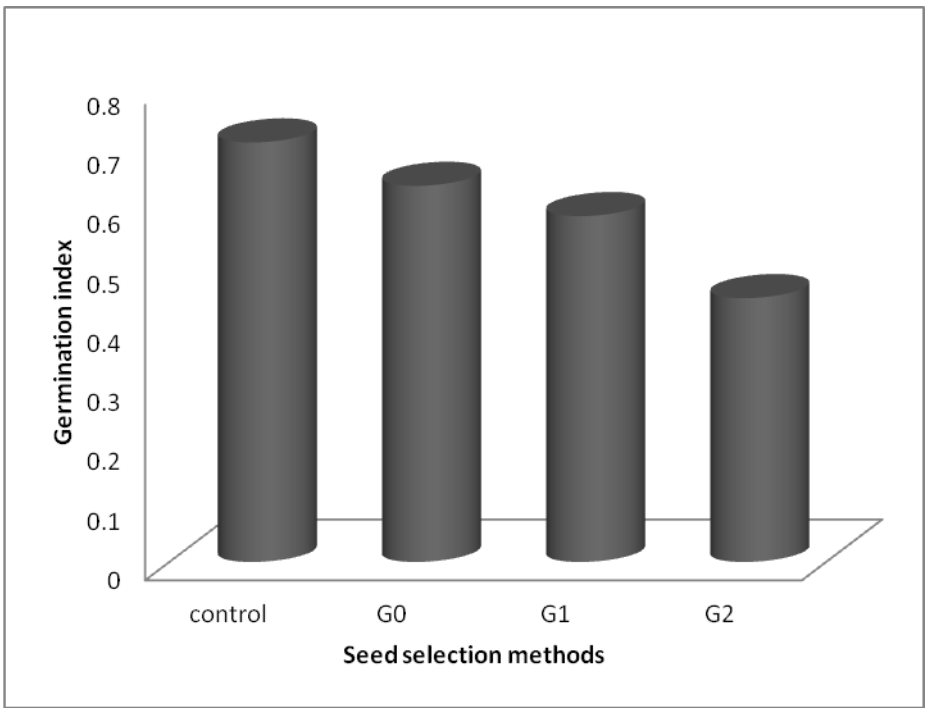

Figure 5: Germination Index(GI)of seeds from different sources; Control, G0;seeds selected in the field,G1; seeds selected after harvest and G2; seeds picked from grains meant for food germinated on TP at 20-30^{o}C for 8 days.

The germination index, GI is a measure of speed of seed germination and the value close to 1.0 would represent the seed of high quality. There was a significant difference at 5% level of significance among the seed selection methods on GI. Bonferroni showed that there was no difference between the control and both the selection from field and after harvest. There was also no significant difference among the three selection methods but there was a difference between the control and selection from grains meant for food. The seeds picked from grains meant for food had the lowest germination index of 0.5 (Figure 5).

4.2.4 The quality of Seeds from Different Sources after AAT

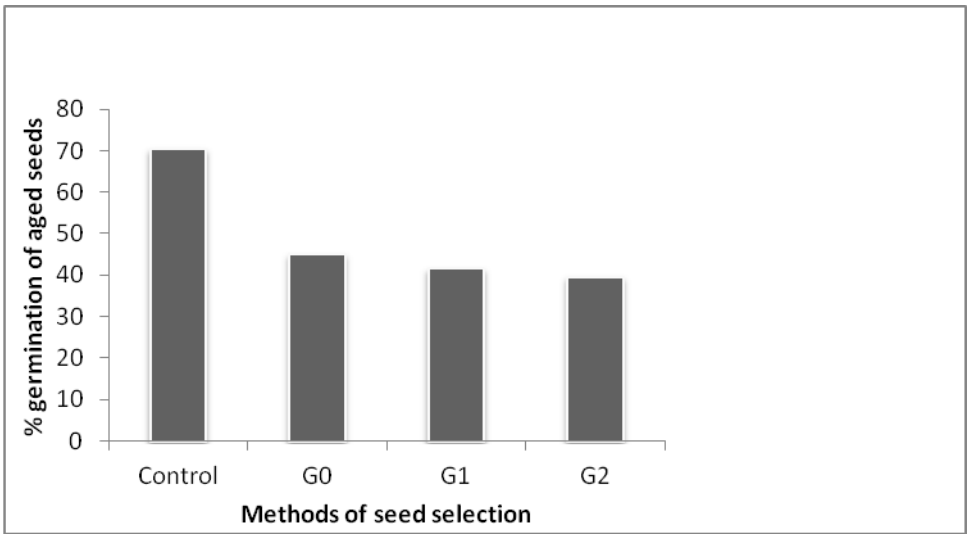

Figure 6. Accelerated ageing of seeds from different sources; Control, G0; seeds selected in the field, G1; seeds selected after harvest and G2; seeds picked from grains meant for food germinated on TP at 20-30^{o}C for 8days.

From figure 6 above, it can be seen that seeds selected from grains meant for food had the lowest germination. The seeds selected from the field were better and slightly higher than those from harvest.

4.2.5 The Effect of Selection Methods on Electrical Conductivity of Fresh Seeds

Seed lots with high electrolyte leakage had high leachate conductivity and were considered as having low vigor while those with low leakage (low conductivity) were considered high vigor. Kruskal Wallis test was used here to demonstrate the differences in their means. The p-value was 0.009 and was statistically significant. The Wilcoxon rank sum test was used to show how methods differed. The results showed that all methods were different from one another. However, the seeds selected from harvest were better than those selected in the field and from grains meant for food as indicated in their respective EC values (Table 9). Thus the selection methods can be ranked from best to worst on the basis of the value of EC. The lower the EC value the better the quality. The lower the conductivity value the tougher the cell membrane and consequently the higher

the quality of the seed. Thus the seeds selection methods can be ordered in this manner; control<selection after harvest<selection from field<selection from grains.

Table 9. Electrical conductivity (EC) values of seeds from different sources. G0; seeds selected in the field, G1; seeds selected from the harvest and G2, seeds picked from grains meant for food.

Treatments	EC
Control	5.021a
G0	5.554c
G1	5.145b
G2	10.117d

4.2.6 The Effect of Selection Methods on Seed Health

The different seed selection methods gave varying degrees of disease infection in the resulting seed lots as shown in the bar graph. The control had the least disease infection but Selection methods used by the farmers had favored disease infection.

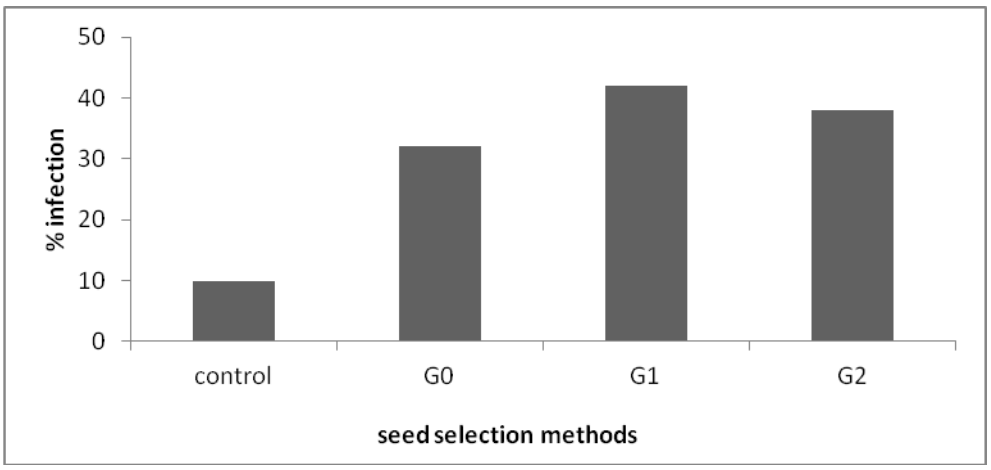

Figure 7: The seed health of seeds from different sources: Control, G0; seeds selected in the field, G1; seeds selected from the harvest and G2; seeds picked from grains meant for food, incubated at 20 ^{o}C for 24h, then deep frozen for 24h thereafter maintained at 20 ^{o}C for 5 days in cycles of 12 h darkness and 12 h daylight.

The one way analysis of variance (ANOVA) was carried out to find out the differences in means and indeed there existed significant differences at 5% level of significance. To establish which

method differed from the other, Bonferroni was performed which indicated that the control differed significantly ($p<0.0125$) with selection from field and from grains. The results showed that there was a marked increase in the rate of infection between the controls the selection methods employed by the farmers. It was also evident that the rate of infection among the selection methods was the same (Figure 7). Selection is an important aspect of seed production as it serves to reduce disease incidence by discarding obviously diseased plants or seeds (sanitary quality).From the results there is an implication that farmers' methods of seed selection were not effective in minimizing infections.

4.3 Testing for Differences among the Seed Processing Methods

4.3.1 Effect of Processing on Seed Moisture Content

Threshing of finger millet seeds from the husks sometimes involves use of mortar and pestle or beating the harvest using sticks. Depending on moisture content, mechanical damage to the seeds can occur resulting in deterioration of vital embryonic tissues and that any break in the seed coat affords an excellent opportunity for fungi to enter the seed, and either kill it, or weaken the seedling that will be produced from it. Results from the effects of processing on moisture content are shown in table 10. The finger millet farmers processed the seeds from different methods. These were threshing panicles immediately after harvest. This meant that the panicles were threshed as soon as they were harvested. The second method was to dry the panicles for some time then thresh and lastly was a situation whereby they kept the panicles in a sack for 6 months then threshed.

Table 10: Percent Seed Moisture Content different methods of processing: Control, P0; threshing panicles immediately after harvest, P1; dry the panicles for some time then thresh and P2; kept the panicles in a sack for 6 months then thresh.

Treatment	%MC
Control	6.8a
P0	7.1a
P1	6.4a
P2	6.1a

The one way analysis of variance (ANOVA) to compare differences was performed and the results showed that there were no statistically significant differences at 5% level of significance between the control, threshing panicles immediately after harvest, drying the panicles for some time then thresh, and keeping the panicles in a sack for 6 months then thresh. The observation show that the moisture content was the same implying that framers had no control over moisture content

4.3.2 Effect of Processing on Analytical Purity Analysis of Finger Millet Seed

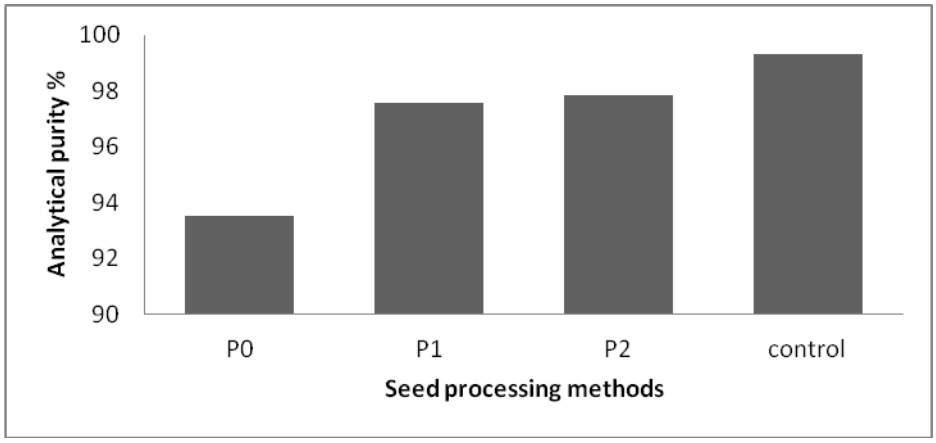

Figure 8: Percent analytical purity of finger millet seeds from different methods of processing P0; threshing panicles immediately after harvest, P1; dry the panicles for some time then thresh,P2; kept the panicles in a sack for 6 months then thresh and Control.

There existed significant differences (p <0.05) between the control differed with the three processing methods used by the farmers namely: threshing panicles immediately after harvest, drying the panicles for some time then thresh and keeping the panicles in a sack for 6 months then thresh and that each of the methods differed from one another (Figure 8). Each of the methods employed by the farmers influenced seed purity at varying percentages.

4.3.3 Effect of Processing on Seed Germination

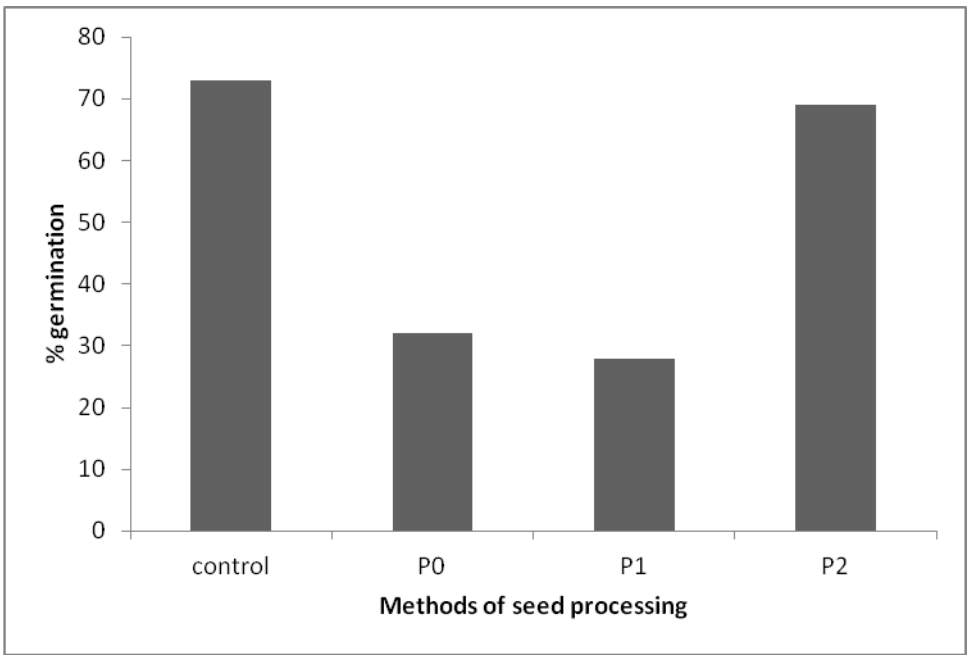

Figure 9: Seed germination of finger millet seeds after different methods of processing; Control, P0; threshing panicles immediately after harvest, P1; dry the panicles for some time then thresh and P2;kept the panicles in a sack for 6 months then thresh.

There were significant differences (P<0.05) between control and threshing panicles immediately after harvest. There were no significant differences between control and keeping the panicles in a sack for 6 months then thresh**.** Threshing panicles immediately after harvest and drying the panicles for some time then thresh had similar effects on seed germination. Keeping the panicles in a sack for 6 months showed a higher germination percentage than the rest of the methods used by the farmers (Figure 9).

4.3.4 Effect of Processing Methods on Electrical Conductivity of Fresh Seeds

There was a significant difference ($p<0.05$) between the control and threshing panicles immediately after harvest but the rest of the processing methods did not differ (Figure 10). Threshing seeds immediately after harvest had the highest EC values than the rest of the methods. Seeds that were threshed immediately after harvest appeared to have a relationship with high electrolyte leakage hence high EC.

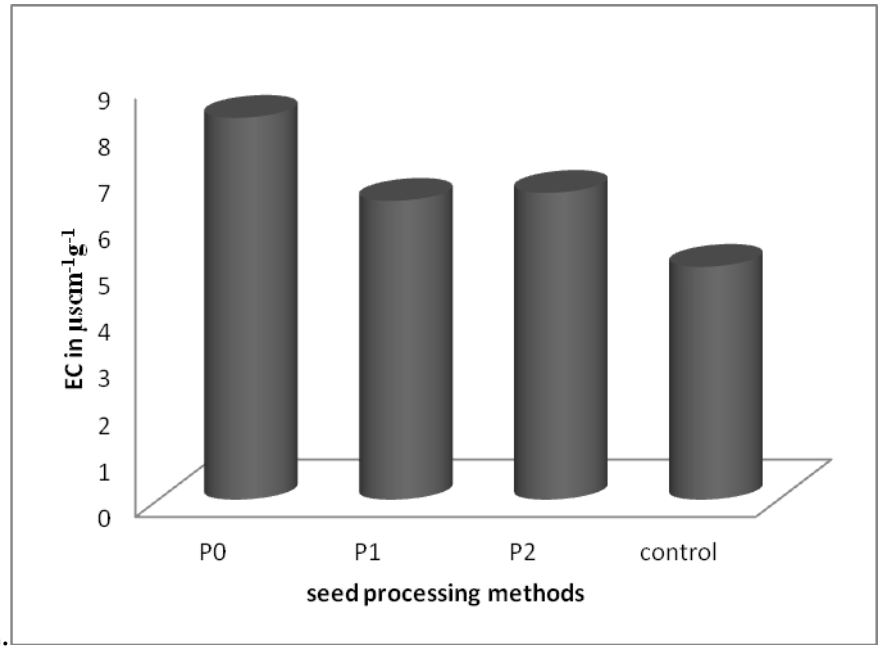

Figure10: Electrical conductivity of fresh finger millet seeds after different methods of processing; P0, threshing panicles immediately after harvest; P1, dry the panicles for some time then thresh;P2,kept the panicles in a sack for 6 months then thresh.

4.3.5 Effect of Seed Processing Methods on Accelerated Ageing (AA) of Seeds

The seeds that were stored for six months before threshing showed a higher germination percentage on AA than the rest (Figure 11). The longer period taken before processing the seed appear to give some strengh to seed to withstand some adverse conditions during ageing.It is only those seeds that are strong that can resist the stress of high temperature and moisture and consequently showed high germination percentage. They were considered to be of high quality.

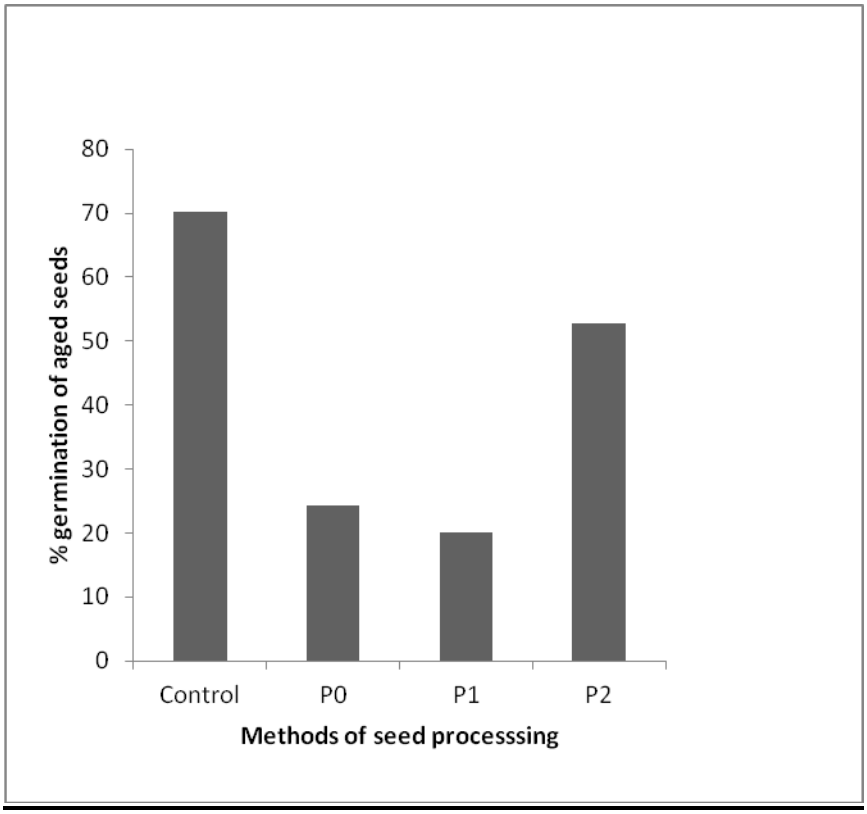

Figure11:Accelerated ageing of finger millet seeds from different methods of processing; Control,P0; threshing panicles immediately after harvest, P1; dry the panicles for some time then thresh and P2;kept the panicles in a sack for 6 months then thresh.

4.3.6 Effect of processing on seed health

There was significant difference ($p<0.05$) between the control and threshing panicles immediately after harvest. There was no significant difference between the control and keeping the panicles in a sack for 6 months then thresh. Processing seeds immediately after harvest and processing after some time have shown the same level of infection. The control and keeping the panicles for 6 months then thresh have the least infection (Figure 12). The findings of the study were in agreement with McCormack (2004) who observed that high seed moisture content increases the respiration rate of seeds, and in turn raises seed temperature which encourage mold growth thus damaging the seeds either slowly or quickly and insects such as weevils can breed causing rapid destruction of seeds in a short period of time.

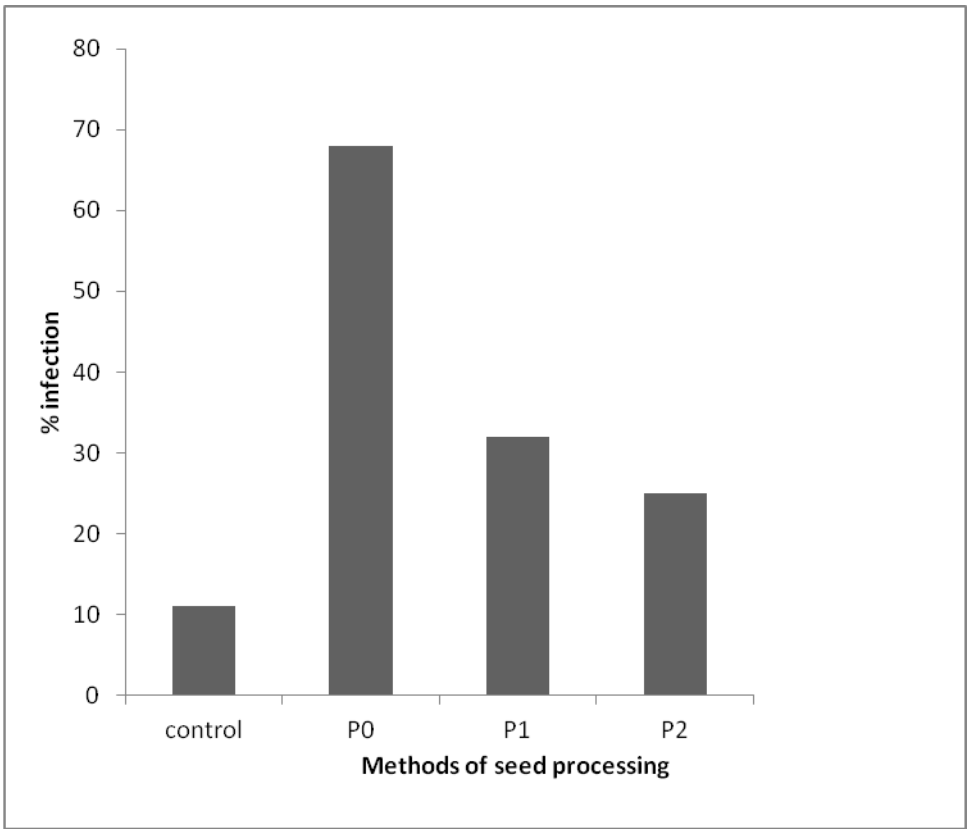

Figure12. Percentage seed infection of finger millet seeds by *Pyricularia grisea* after different methods of processing; Control, P0; threshing panicles immediately after

harvest, P1; dry the panicles for some time then thresh and P2; kept the panicles in a sack for 6 months then thresh.

4.4 Testing for differences among the seed storage methods

4.4.1 Effect of storage on seed moisture content

There were no significant differences between moisture content mean values of the control and the three methods of seed storage used by the farmers (Figure 13). Traditional storage methods were not efficient though comparatively cheap and accessible to farmers. The moisture content in the seeds were never controlled hence the seeds in all the storage methods lost or got relatively same amount.

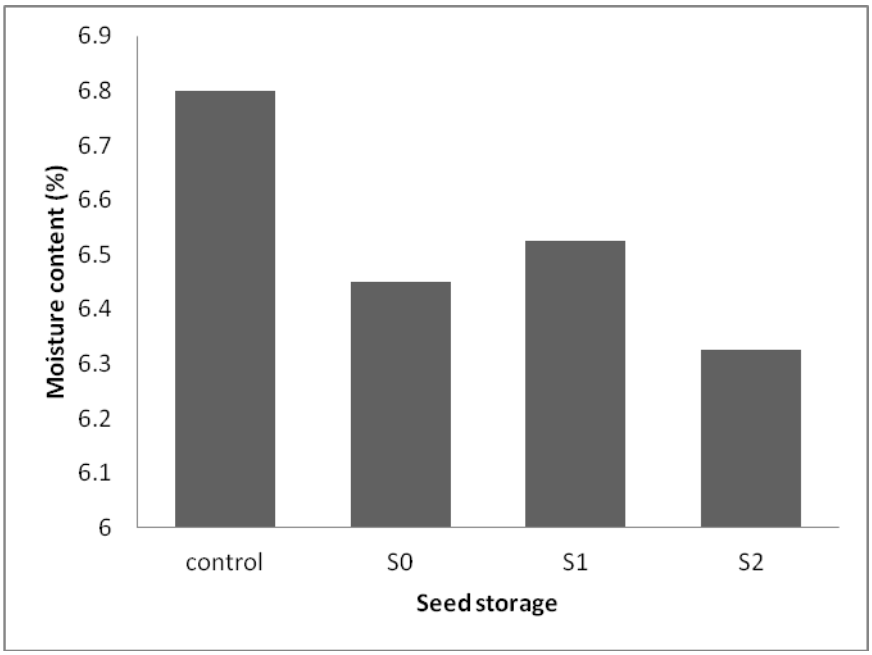

Figure 13.Percent seed moisture content of finger millet seeds stored under different conditions: S0, seeds stored in tins; S1, seeds stored in sacks and S2, seeds stored above fire place.

4.4.2 Effect of storage on seed germination

Table 11: Seed germination of seed lots expressed in percentage stored under different conditions: S0, seeds stored in tins; S1, seeds stored in sacks and S2, seeds stored above fire place.

Treatment	% germination
control	73a
S0	41c
S1	52b
S2	39cd

*values with same letters are not different ($p<0.0125$) Bonferroni

The analysis of variance (ANOVA) was carried out to compare the means and the results suggested that there existed a statistically significant difference at 5% level of significance. The seed germination percentages were far much below the acceptable standards for finger millets in Kenya of 70% and above (Sikenyi, 2010) .Bonferroni was used to establish which of the storage methods had the difference and the results showed that the control and all the farmers seed storage methods were significantly different ($p<0.0125$). Seeds stored in tins and seeds stored in sacks differed significantly ($p<0.0125$) and similar observation was also noted between seeds stored in sacks and those above fire place. There was, however, no significance between seeds store in tins and those above fire place (Table 11).

4.4.3 Effect of storage of fresh finger millet seeds as measured by GI

The storage methods had different effects on the Germination index of the seeds. The significant differences were noted at 5% level of significance. To establish which of the

methods had the difference, Bonferroni was performed and it was found out that the control differed significantly ($p<0.05$) with seeds stored in tins and seeds stored in sacks but the rest of the methods within themselves did not differ (Figure 14).

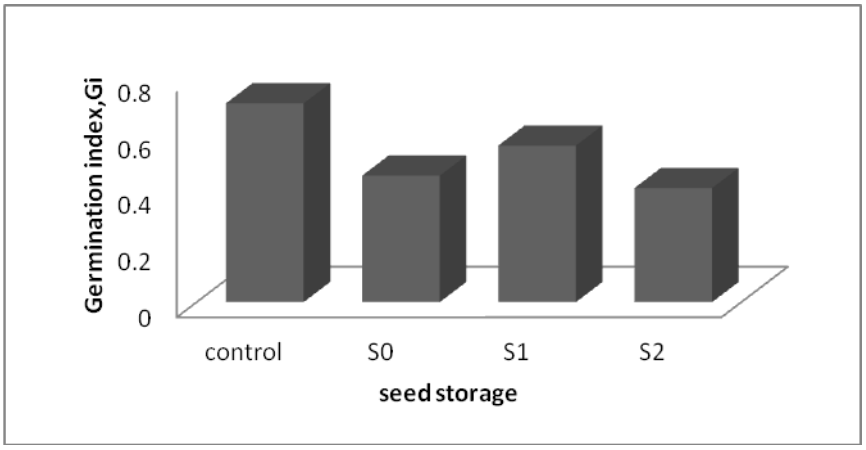

Figure 14: Effect of storage of fresh finger millet seeds under different conditions: Control, S0; seeds stored in tins, S1; seeds stored in sacks and S2; seeds stored above fire place.

4.4.4 Effect of storage on Accelerated ageing of the seeds

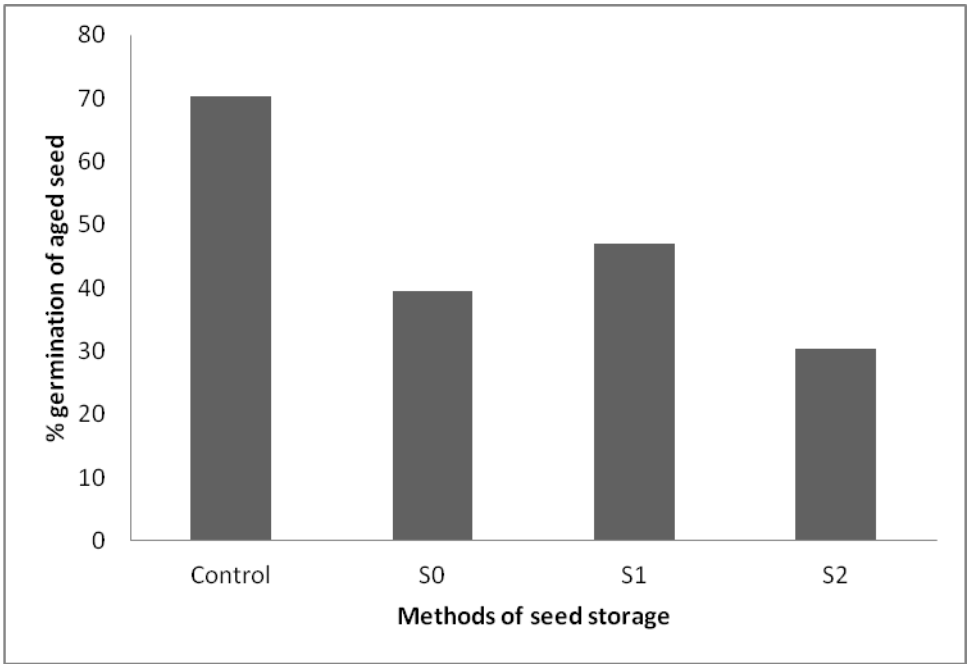

Figure 15.Accelerated ageing of seeds under different storage conditions: S0, seeds stored in tins; S1, seeds stored in sacks and S2, seeds stored above fire place.

All the selection methods had statistically significant effect on accelerated ageing of the seeds when compared with the control ($P<0.05$).The methods amongst themselves did produce similar effects (Figure 15).

4.4.5 Effect of storage on Electrical conductivity of fresh seeds

4.4.5.1 Comparisons of EC of fresh and aged finger millet seeds

The EC values for the fresh finger millet seeds were relatively the same between seeds stored in tins and those stored in sacks but increased in stored above fire place (Figure 16). The EC values for the aged seeds of finger millet took an increasing approach from the control and the last were those stored above fire places. The higher EC values are indications of more leachates from the seeds as result of a weaker membrane. It could be inferred from the above observation that seeds that were exposed to prolonged heat though they may have low moisture content exhibited lower quality characteristics.

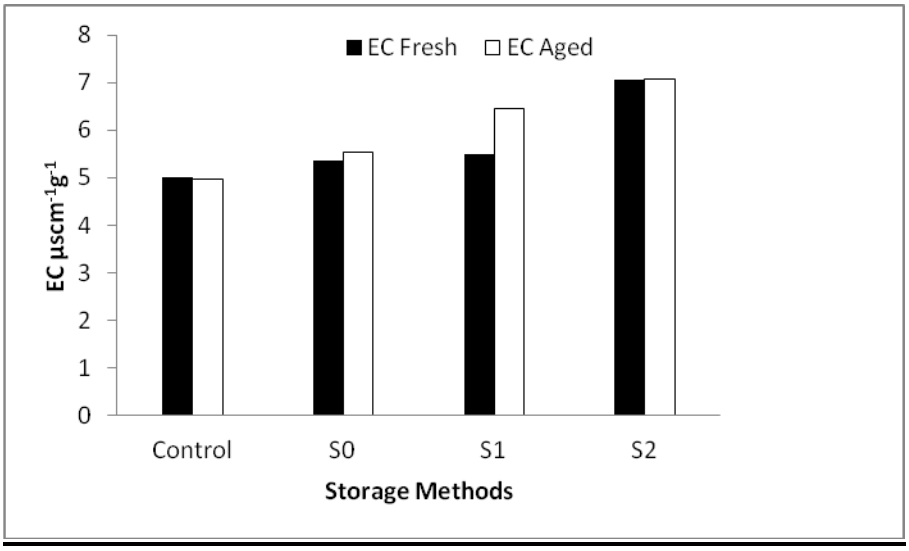

Figure 16: Comparisons of EC of fresh and aged finger millet seeds under different conditions: S0, seeds stored in tins; S1, seeds stored in sacks and S2, seeds stored above fire place.

4.4.6 Effect of storage on seed health

Table 12: The rate of seed infection under different storage conditions; S0 (stored seeds in tins), S1 (stored seeds in sacks) and S2 (stored seeds above fire place).

Treatments	% infection
Control	11.00d
S0	44.75b
S1	34.25bc
S2	71.50a

*values with same letters are not different, (0.0125) Bonferroni.

The three storage methods showed different levels of seed infection. Significant differences ($p<0.05$) existed between the control and the three methods of seed storage (Table 12). It was also found that there was a difference in infection between seeds stored in tins and those stored above fire place. The infection was the same in seeds stored in tins with those stored in the sacks. There was high infection in seeds stored above fire place. The seeds store above fire places were exposed to high temperatures and it appeared that higher temperatures favored seed infection.

CHAPTER FIVE

DISCUSSIONS

5.1 Seed Supply

5.1.1 Distribution of the Farmers in the Division, Level of their Education and the Sources of Seed.

The distribution of finger millet farmers across the six locations of Soin division was even. It meant that no one location had any advantage over another in terms of growing millet. The level of education among these farmers was inversely proportional to their experience in the growing of finger millet. Based on the educational, level it could be deduced that these farmers lacked knowledge and technology even though they have grown the crop for a long period. The results suggested that they obtained their seeds from different sources but that the informal seed supply system was the main source of the seeds of finger millet.

The findings of this study agreed with both Ayieko and Tschirley (2006) and that of Wekundah (2012) that approximately 80% of all seed used in Kenya comes from the informal sector where farm-saved seed was the key source of seed. Quite a small proportion of the farmers obtained seeds from the formal seed supply system. This observation confirmed the earlier view (Kute *et al.,* 2000) that finger millet seeds from the formal sector in Kenya were limited.

5.1.2 Seed Selection

Typically, farmers designate some of their harvest as “seed,” treat and store it separately from grain, and only sow from this the following season (McGuire, 2007). In this study majority of the farmers select the seeds while the crop is in the field. They used certain indicators such as changing color, thicknesses and the firmness of the grains, and the

folding in and out of the fingers. During harvesting time, identified panicles intended for seeds were cut by leaving a longer stalk than the rest and put in one sack. The panicles with longer stalks would be separated easily from the rest at home before threshing. It was noted however that not all finger millet folded their fingers even after maturity as this was unique to some varieties (Upadhyaya *et al*., 2007).Due to their limited education, the farmers lacked information on certain important stages of seed development such as physiological maturity (PM) and harvest maturity (HM).The specific time to select the seed while in the field greatly affect the vigor. Seed quality is highest at physiological maturity and this important aspect was missed out as majority of them selected the seeds based on the folding out of the fingers ,which is a genotype controlled characteristic rather than maturity characteristic (Upadhyaya *et al*., 2007).

Selection of seeds after harvest resulted in admixtures as it was not possible to differentiate seed varieties and at times farmers used the grains meant for food as seeds. This study observed that those seeds picked from grains meant for food had a lower germination than those selected in the field. The quality aspect of seed did not matter here as what was found at that moment would be sown. Similar observations had been made by TeKrony (2006) but this method was risky as farmers could consume all the seeds as food in cases of food shortage and miss planting materials in the subsequent seasons.

5.1.3 Seed Processing

Panicles were threshed to remove the seed from the surrounding plant material and this sometimes involved use of mortar and pestle or beating the harvest using sticks. Seeds received from the field were often at high moisture content and may have deteriorated. Seed processing was necessary to dry the seeds to a safe moisture level, remove or reduce the level of undesirable material and deteriorated and damaged seeds. Threshing panicles immediately after harvest resulted in a number of grains getting broken due to high

moisture content and this definitely affected the germinating power of the seed (Maryam and Oskouie, 2011). A large proportion of farmers kept the panicles inside the sacks for some time even up to six months before threshing. Planting of the crop is done once per year and threshing is done to coincide with planting time and also as a means to safeguard the seeds from being consumed as food. It was observed that threshing under such circumstances was not easy because the sack provided a microclimate of high moisture and therefore panicles would appear damp.

5.1.4 Seed storage

It was observed that finger millet farmers stored the seeds in three distinct places namely; in tins, sacks and above fire place. Majority of them put the seeds in sacks and kept above fire place. The air and smoke above the fire place was hot enough and was believed to keep the seeds dry.

The smoke has a chemical substance known as butenolide (Kulkarni *et al*, 2011) and can stimulate germination (Modi, 2004). The seeds kept in the tins and sacks were first sun dried before such storage was made. The preferred sacks were made of polythene and sisal fibres. The sacks were porous and could allow moisture into the seeds.

5.2 Seed Quality

The seed quality attributes were found to be influenced by selection, processing and storage as were used by the farmers.

5.2.1 Moisture Content (MC)

The moisture content (MC) of the finger millet seeds was not significantly affected by the selection, processing and storage. According to McCormack (2004) the safe moisture content regime for most seeds is between 5% and 14%. Low seed moisture content is a pre-requisite for long-term storage, and is the most important factor affecting longevity

however seeds lose viability and vigor during processing and storage mainly because of high seed moisture content (seed moisture greater than 18%). Excessively high drying air temperatures are deleterious to the seed (Hill and Johnstone, 1985) and this was suspected to be the cause of poor germination because farmers had no control over temperature once the seeds were kept above fire place.

5.2.2 Analytical Purity

There was evidence of contamination of the seeds either during seed selection or during processing. It was observed that some farmers used folding- in of the fingers as an indication of ripening/maturity stage of the seeds as their criterion for selection. The folding-in of the fingers of millet is variety specific (Upadhyaya *et al*., 2007) and therefore using this as an indicator for selecting mature panicles would ended up in the mixing of different varieties of the seeds hence compromised the purity.

During processing, seeds were threshed to remove the surrounding plant material and a period of air-drying was important before seeds are threshed. Threshing of finger millet grains using mortar and pestle or beating with sticks led mechanical damage to the seeds resulting in deterioration of vital embryonic tissues (Maryam and Oskouie, 2011). Threshing immediately after harvesting resulted in low germination and higher EC values due to high mechanical damage.

5.2.3 Seed Germination

None of the selection methods produced seeds whose germination percentage was close to 70% and were all significantly different($p<0.05$). Although the majority of the farmers indicated that they selected the seeds in the field, they lacked knowledge of certain pertinent aspects of seed maturation. That could account for the differences in seed germination among the selection methods and would imply that seeds were either picked

too early or too late. Processing immediately after PM resulted in more grains getting broken from the mechanical effect of either pounding or beating causing damage to the seed since the testa was not dried enough to provide necessary strength. The seed storage methods seriously affected seed germination.

The findings of this study agreed with the observation of (Vanek&Hobbeg, 1992; Okiror *et al.,* 2001; Kabeere, 2001) that storage conditions at farmers' level further complicate quality as there was no control on temperature and humidity as well as aeration. Those conditions for seed storage were not the same as those for grain storage. The seeds stored above fire places had low moisture content but still seed germination was not significantly different from those seeds stored in tins.

Seeds stored above fire place got smoke, and was expected to improve in germination percentage (Modi, 2004) because of natural growth stimulating substance known as butenolide(Smith, 2006; Kulkarni *et al.,* 2011) but did not occur. Excessive high air temperatures was suspected to cause decline in germination of the seeds

5.2.4 Seed Vigor

Germination index is an indicative of the vigor of the seed lot. McDonald (1997) observed that seed vigor was affected by the time of harvest after PM is reached. This means that timely harvesting (selection while in the field) could result in good performance of the seeds. Seed quality is highest at physiological maturity (PM) (Khatun *et al.,* 2010; Olasoji *et al.,* 2012,).In this study the control (certified seeds) was significantly different from seeds picked from grains meant for food.

The study found out that seeds selected in the field and after harvest gave higher GI values implying that their experience in the growing of finger millet contributed to some extent to this seed quality attribute. Processing methods did not have any significant

influence in the germination index but storage of seeds in tins and above fire places was found to be significantly lower than the control. Accelerated ageing (AA) results showed that all the seed selection methods used by the finger millet farmers gave similar results but were different from the control.

All the processing methods used by these farmers did not have significant effect on the results as measured by AA. Similarly storing the seeds in the tins and above the fire places did not have significant differences as shown by AA values. The tins favored built up of moisture which is not safe for storage (McCormack, 2004) whereas storage above fire place provided high temperatures which were injurious to the seeds (Hill and Johnstone, 1985). Hence both were not ideal storage conditions for the finger millet seeds.

Seed lots with high electrolyte leakage had high Electrical conductivity (EC) and were considered as having low vigor while those with low leakage (low conductivity) were considered of high vigor. The electrolyte leakage is related closely to the membrane integrity of the seeds. While those seeds selected from grains meant for food had the highest EC implying that storage conditions for the seeds should not be the same as those intended for food (Fatima, 1999).

It was also observed that seeds threshed immediately after harvest had the highest EC. The pounding and/or beating of the seed at this time seemed to have affected the membrane integrity of the seed. Apart from the two observations made concerning the EC, it was found that seeds stored directly above fire place also exhibited high EC. The injury caused by excessive heat could have caused the decline in the integrity of the membrane of the seed.

5.2.5 Seed Health

Seeds selected while in the field did not differ in percent infection with the control. This observation was similar to that made by Sreenivasaprasad *et al*., (2004) found that farmers have the knowledge of the disease but do not know the mode of transmission and the only way to avoid diseases was to select seeds from healthy looking panicles.

Seeds selected from the harvest and selecting seeds from grains meant for food were however found to differ greatly from the control. There were no significant differences in infections of the seeds amongst seed selection methods used by the farmers. While those seeds processed immediately after harvest had more infections compared to those kept for some time to dry up. It was most likely that during processing, testa was damaged since it is soft and it provided entry point for infection. Seeds were dried then threshed did not differ significantly in terms of infection with the control.

This observation was in agreement with McCormack (2004) who noted that plant materials should be spread out in thin layers until all plant materials area dry; otherwise, mold, decay, and heat would cause damage to the seeds. Storing seeds in tins and in sacks did not differ in terms of infections but storing seeds above fireplace exhibited more infections than the control.

There were differences in terms of infection also between storing seeds in sacks and above fire place. Differences could be a result of variations in temperature and relative humidity as seeds were kept inside the sacks. Similar observation had been obtained by Niaz and Sitara (2011) on seed maize stored at 26 %MC and at a temperature of 40^{o}C.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. The results indicated that farmers from all the locations of Soin division in Kericho County obtained seeds from different sources and that the informal seed supply system was their main source of finger millet seeds.
2. The quality of the finger millet seeds used by the farmers in Soin division was low in all the quality aspects investigated.
3. Seed selection, processing and storage methods which farmers used in the production of the seeds in Soin division compromised the seed quality.

6.2 Recommendations

1. Finger millet farmers in Soin division of Kericho County should be encouraged to source the high quality finger millet seeds. The formal seed supply sector is more assured in terms of quality.

2. Since the majority of the finger millet farmers obtained their seeds from the informal seed supply, there is need to boost their knowledge on the importance of using quality seeds in successful farming activities. This is because the majority of farmers had primary level of education.

3. Improved seed production technologies should be availed to these farmers in an attempt to boosting high quality seed supply through training on seed selection criteria and proper post-harvest handling of the seed.

6.3 Suggestions for Further Research

Further research is needed to improve quality of seed in the informal system especially in seed processing and storage.

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APPENDICES

APPENDIX I: QUESTIONNAIRE FOR ON-FARM FINGER MILLET SEED PRODUCTION BY SMALL SCALE FARMERS IN SOIN DIVISION OF KERICHO DISTRICT

Guidelines

- The information you provide will be treated with utmost confidentiality
- Answer ALL questions in this questionnaire
- There are no correct answers but the one you give are the correct ones

1] GENERAL INFORMATION ON THE FARMER

a) Indicate your location of residence

i) Soliat [ ]
ii) Koitaburot [ ]
iii) Kaitui [ ]
iv) Kapsorok [ ]
v) Kapsegut [ ]
vi) Soin [ ]

b) Show your level of education from the choices given below

i) never attended any formal education [ ]
ii) primary level [ ]
iii) secondary level [ ]
iv) college [ ]
v) university [ ]
vi) others [ ]

c) How long have you participated in the growing of finger millet?

i) 1-5years [ ]
ii) 6-10 years [ ]
iii) 11-15 years [ ]
iv) 16-20 years [ ]
v) above 21 years [ ]

2] SOURCES OF FINGER MILLET SEEDS

a) Do you source finger millet seeds from a seed company?

i) Yes [ ] ii) no [ ]

b) Give a reason for sourcing finger millet seeds from company

i) Properly cleaned and high quality ii) resistance to diseases iii) resistance to drought iv) early maturing v) high yielding vi) resistance to pests vii) resistance to lodging

c) Do you have other sources of finger millet seeds?

i) own saved seeds ii) other farmers ii) market iv) others

d) If you got your seeds in c

(i) above, what was your selection method?

i) Identifying panicles while in the field ii) select from the harvest

iii) from grains meant for food

e) Pick from the list given an indicator which you used to select your seed while in the field

i) Changing of color of the panicles ii) thickening and firmness of the grains in the fingers iii) folding in of the finger iv) folding out of the fingers

3] PROCESSING OF FINGER MILLET SEEDS

When did you thresh the panicles so as to get seeds/grains?

i) Immediately after harvest ii) sundried the panicles for some time iii) kept the harvested panicles in a sack for some time

4] METHOD OF SEED STORAGE

Where did you store your seeds after threshing?

i) in tins ii) in sacks iii) above fireplace

5] SEED TREATMENT

The following are different methods of treating seeds; pick the one you used to treat your seeds.

i) used ash ii) used dry cow dung iii) chemicals bought from agro shop iv) use smoke v) others

Thank you most sincerely for your contribution

By:
David Kiplangat Ng'eno(AGR/PGC/01/06)
M.Phil. Seed Science and Technology
University of Eldoret.

APPENDIX II: PERMIT FROM THE DISTRICT COMMISSIONER, KERICHO DISTRICT

OFFICE OF THE PRESIDENT

Telegrams: .....
Telephone: Kericho 20131/2/4
When replying please quote
Ref. No. ADM. 15/3 VOL.VII/23
and date

THE DISTRICT COMMISSIONER
KERICHO DISTRICT
P.O. Box 19-20200
KERICHO

31ST OCTOBER 2008

TO DISTRICT OFFICERS
(1) SOIN DIVISION
(2) AINAMOI DIVISION

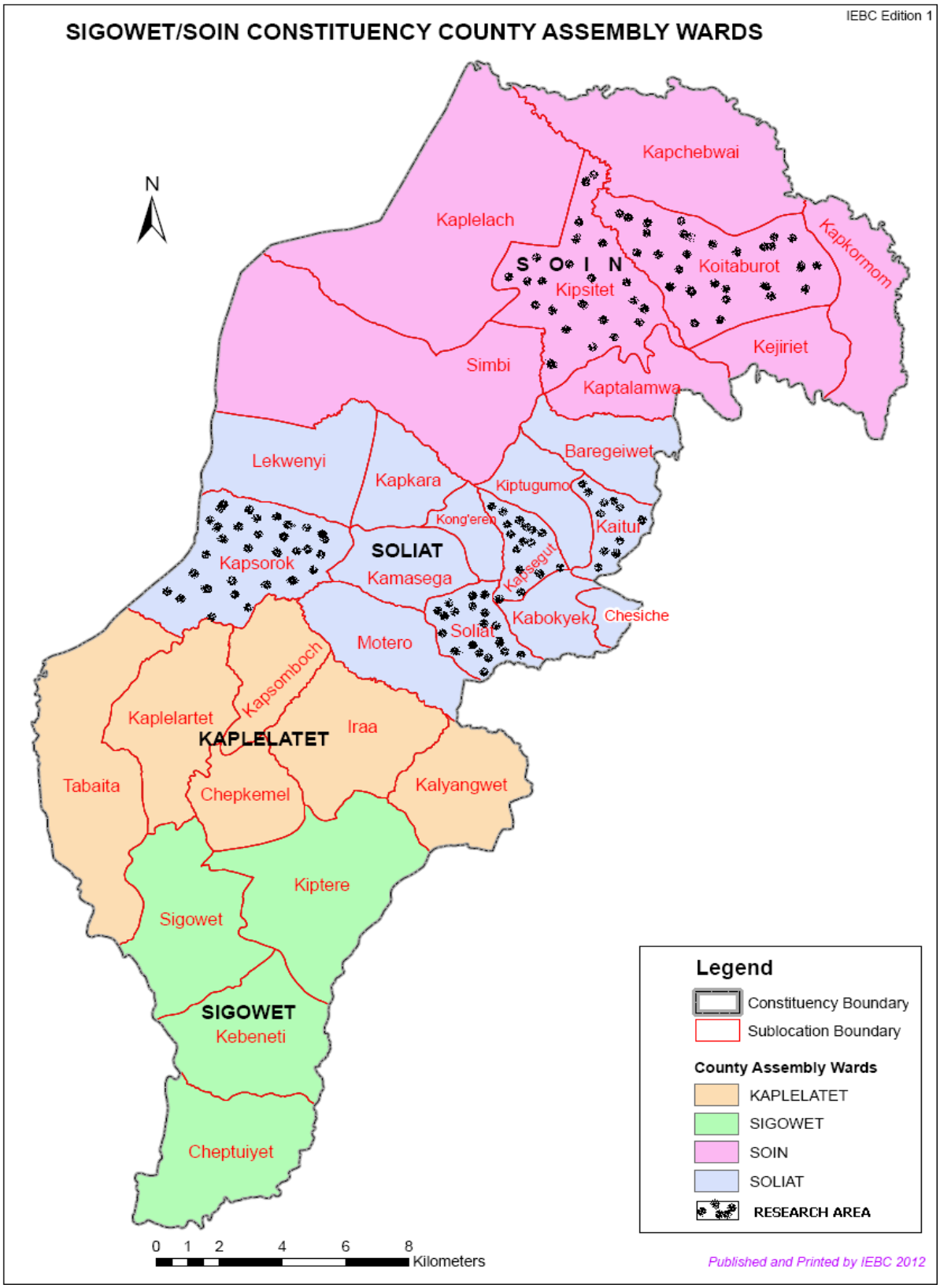
RE: DAVID KIPLANGAT NGENO - ADM. NO.AGR/PGC/01/06 - TSC 336683.

The above named who has successfully completed his course work at Moi University on quality aspects on finger millet seeds has been authorised to do research on the same within your Divisions.

Please accord him the necessary assistance.

W.O. MANYWANDA
FOR: DISTRICT COMMISSIONER
KERICHO.

APPENDIX III: RESEARCH AREA OF SOIN DIVISION OF KERICHO DISTRICT



Adapted from IEBC and Modified (Research area inserted) by Author.

APPENDIX IV: DESCRIPTIVE STATISTICS OF THE CHARACTERISTICS OF FINGER MILLET FARMERS OF SOIN DIVISION

Characteristic		n (%)
Location	Soliat	28 (15.8)
	Koitaburot	30 (16.9)
	Kaitui	31 (17.5)
	Kapsorok	25 (14.1)
	Kapsegut	31 (17.5)
	Soin	32 (18.1)
Education level	never attended formal education	24 (13.6)
	primary education	91 (51.4)
	secondary education	36 (20.3)
	college	26 (14.7)
Experience on finger millet	1-5 years	37 (20.9)
	6-10 years	22 (12.4)
	11-15years	34 (19.2)
	16-20 years	38 (21.5)
	above 21 years	46 (26.0)
Sourcing seed from seed company	yes	22 (12.4)
	no	155 (87.6)
Reasons for sourcing seeds from company	Resistance to diseases	5 (2.8)
	Resistance to drought	1 (.6)
	Early maturing	12 (6.8)
	High yielding	4 (2.3)
	Missing data	155 (87.6)
Other sources of finger millet	Own saved seeds	71 (40.1)
	Other farmers	61 (34.5)
	Market	45 (25.4)
Method of seed selection	identify specific panicles while in the field	125 (70.6)
	select panicles from the harvest	48 (27.1)
	from grains meant for food	4 (2.3)
Indicators of seed selection	changing of the color of panicles	25 (14.1)
	thickness and firmness of the grains in the fingers	19 (10.7)
	folding in of the fingers	10 (5.6)
	Folding out of the fingers	123 (69.5)
Processing methods	thresh panicles immediately after harvest and dry the grains	31 (17.5)
	dry the harvested panicles and thresh	28 (15.8)
	keep the harvested panicles in a sack for some time then thresh	118 (66.7)
Storage methods	Tins	27 (15.3)
	Sacks	66 (37.3)
	above fire place	82 (46.3)
	Missing data	2 (1.1)
Treatment methods	Ash	23 (13.0)
	Chemicals from agro-shop	13 (7.3)
	Smoke	2 (1.1)
	Missing data	139 (78.5)

APPENDIX V: SUMMARY STATISTICS, MEAN (SD), AND THE COMPARISON OF MEANS OF THE SEED QUALITY PROPERTIES STRATIFIED BY SELECTION, STORAGE AND PROCESSING METHODS

Characteristic		V1	V2	V3	V4	V5	V6	V7	V8	V9
	control	6.8	72.8	5.0	5.0	11.0	70.3	0.7	0.7	99.3
		(0.57)	(5.12)	(0.38)	(0.41)	(2.94)	(7.04)	(0.12)	(0.10)	(0.03)
Seed	G0	8.1	58.8	5.6	7.6	35.3	45.0	0.6	0.6	98.4
selection		(0.83)	(2.22)	(0.25)	(2.50)	(8.96)	(6.48)	(0.03)	(0.05)	(0.18)
	G1	6.9	52.2	5.1	5.2	43.5	41.5	0.6	0.5	96.9
		(1.30)	(3.30)	(0.12)	(0.16)	(6.66)	(6.56)	(0.04)	(0.09)	(0.15)
	G2	6.6	45.0	10.1	8.9	36.8	39.3	0.44	0.4	93.5
		(1.07)	(2.00)	(0.75)	(2.26)	(13.40)	(0.96)	(0.04)	(0.02)	(0.21)
F test	p-value	0.177	0.000	0.009*	0.009*	0.001	0.000	0.001	0.001	0.000
Seed	P0	7.1	32.0	8.2	8.2	69	24.3	0.3	0.2	93.5
processing		(0.33)	(1.83)	(0.58)	(1.05)	(3.37)	(3.86)	(0.01)	(0.03)	(0.13)
	P1	6.4	24.0	6.4	6.4	31.5	20.0	0.3	0.2	97.6
		(0.38)	(2.45)	(0.31)	(1.86)	(7.59)	(1.63)	(0.04)	(0.05)	(0.04)
	P2	6.1	67	6.6	6.6	21.8	52.8	0.7	0.6	97.8
		(0.63)	(4.16)	(0.64)	(0.83)	(2.36)	(11.90)	(0.08)	(0.11)	(0.15)
F test	p-value	0.083	0.000	0.000	0.016	0.000	0.004*	0.010*	0.000	0.000
Seed	S0	6.4	40.8	5.4	5.5	44.8	29.5	0.4	0.3	98.2
storage		(1.19)	(2.50)	(0.12)	(0.08)	(7.27)	(3.70)	(0.02)	(0.04)	(0.05)
	S1	6.5	52.3	5.5	6.5	34.3	47.0	0.6	0.5	98.3
		(1.18)	(0.96)	(0.29)	(2.00)	(13.72)	(3.37)	(0.07)	(0.04)	(0.05)
	S2	6.3	38.5	7.1	7.1	71.5	30.3	0.4	0.3	98.1
		(0.39)	(3.79)	(0.18)	(0.36)	(3.42)	(1.71)	(0.5)	(0.01)	(0.08)
F test	p-value	0.897	0.000	0.000	0.020*	0.000	0.000	0.001	0.005*	0.000

* Kruskal-Wallis test

V1- moisture content in percentage,V2-Germination percentage,V3-Electrical conductivity of the fresh seeds in μScm-1g-1,V4-Electrical conductivity for the aged seeds in μScm-1g-1,V5-Seed health- % of infected seeds,V6-germination percentage of the aged seeds,V7-Germination index for fresh seeds,V8-Germination index for aged seeds, V9-percentage purity G0-selection of panicles while in the field, G1-selection from the harvest, G2-selection from grains meant for food, P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh,

S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place.

APPENDIX VI: BONFERRONI MULTIPLE COMPARISONS TEST AND THE WILCOXON RANK SUM TEST P-VALUES FOR THE DIFFERENCES IN THE AVERAGE VALUES OF THE SEED QUALITY PROPERTIES

Seed quality property		Seed selection methods				Seed processing methods				Seed storage methods		
		Control	G0	G1		Control	P0	P1		Control	S0	S1
V2	G0	0.000			P0	0.000			S0	0.000		
	G1	0.000	0.114		P1	0.000	0.054		S1	0.000	0.003	
	G2	0.000	0.001	0.064	P2	0.271	0.000	0.000	S2	0.000	1.000	0.001
V3	G0	0.110*			P0	0.000			S0	0.472		
	G1	1.000*	0.021*		P1	0.009	0.002		S1	0.140	1.000	
	G2	0.021*	0.021*	0.021*	P2	0.004	0.004	1.000	S2	0.000	0.000	0.000
V4	G0	0.021*			P0	0.012			S0	0.021*		
	G1	0.773*	0.021*		P1	0.634	0.300		S1	0.083*	0.773*	
	G2	0.021*	0.387*	0.021*	P2	0.396	0.485	1.000	S2	0.021*	0.021*	0.248*
V5	G0	0.013			P0	0.000			S0	0.000		
	G1	0.001	1.000		P1	0.000	0.000		S1	0.009	0.547	
	G2	0.009	1.000	1.000	P2	0.036	0.000	0.064	S2	0.000	0.003	0.000
V6	G0	0.000			P0	0.021*			S0	0.000		
	G1	0.000	1.000		P1	0.020*	0.101*		S1	0.000	0.001	
	G2	0.000	1.000	1.000	P2	0.021*	0.021*	0.020*	S2	0.000	1.000	0.001
V7	G0	0.992			P0	0.021*			S0	0.002		
	G1	0.164	1.000		P1	0.021*	0.773*		S1	0.091	0.409	
	G2	0.001	0.014	0.092	P2	0.773*	0.021*	0.021*	S2	0.001	1.000	0.090
V8	G0	0.126			P0	0.000			S0	0.021*		
	G1	0.010	1.000		P1	0.000	1.000		S1	0.021*	0.021*	
	G2	0.000	0.035	0.433	P2	1.000	0.000	0.000	S2	0.020*	0.772*	0.020*
V9	G0	0.000			P0	0.000			S0	0.000		
	G1	0.000	0.000		P1	0.000	0.000		S1	0.000	1.000	
	G2	0.000	0.000	0.000	P2	0.000	0.000	0.011	S2	0.000	0.029	0.005

* Wilcoxon rank sum test

V1- moisture content in percentage,V2-Germination percentage,V3-Electrical conductivity of the fresh seeds in μScm-1g-1,V4-Electrical conductivity for the aged seeds in μScm-1g-1,V5-Seed health- % of infected seeds,V6-germination percentage of the aged seeds,V7-Germination index for fresh seeds,V8-Germination index for aged seeds,V9-percentage purity,

G0-selection of panicles while in the field, G1-selection from the harvest, G2-selection from grains meant for food,

P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh,

S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place.

APPENDIX VII: ANOVA AND KRUSKAL WALLIS TABLES FOR SEED SELECTION METHODS

ANOVA table for testing for differences moisture content in percentage among the following seed selection methods G0-selection of panicles while in the field, G1-selection from the harvest and G2-selection from grains meant for food

Analysis of variance

Source	SS	Df	MS	F	p-value
Between groups	5.61	3	1.87	1.94	0.177
Within groups	11.55	12	0.96		
Total	17.16	15	1.14		

Kruskall Wallis test for differences in V9-Analytical purity among the following seed selection methods G0-selection of panicles while in the field, G1-selection from the harvest and G2-selection from grains meant for food

Seed selection methods	Obs	Rank Sum
Control	4	58.00
G0	4	42.00
G1	4	26.00
G2	4	10.00

Chi-Squared=14.12 with 3 df, probability=0.003

ANOVA table for testing for differences in V2- Seed Germination of fresh seeds among the following seed selection methods G0-selection of panicles while in the field, G1-selection from the harvest and G2-selection from grains meant for food

Analysis of variance					
Source	SS	Df	MS	F	p-value
Between groups	1670.18	3	556.73	48.32	0.000
Within groups	138.25	12	11.52		
Total	1808.44	15	120.56		

ANOVA table for testing for differences in V7-Germination index for fresh seeds among the following seed selection methods G0-selection of panicles while in the field, G1-selection from the harvest and G2-selection from grains meant for food

Analysis of variance					
Source	SS	Df	MS	F	p-value
Between groups	0.15	3	0.05	10.14	0.001
Within groups	0.06	12	0.005		
Total	0.20	15	0.01		

ANOVA table for testing for differences in V6-germination percentage of the aged seeds among the following seed selection methods G0-selection of panicles while in the field, G1-selection from the harvest and G2-selection from grains meant for food.

Analysis of variance					
Source	SS	Df	MS	F	p-value
Between groups	2475.50	3	825.17	24.36	0.000
Within groups	406.50	12	33.88		
Total	2882	15	192.13		

ANOVA table for testing for differences in V8-Germination index for aged seeds among the following seed selection methods G0-selection of panicles while in the field, G1-selection from the harvest and G2-selection from grains meant for food

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	0.20	3	0.07	12.70	0.001
Within groups	0.06	12	0.01		
Total	0.26	15	0.02		

Kruskall Wallis test for differences in V3-Electrical conductivity of the fresh seeds in µScm-1g-1 among the following seed selection methods G0-selection of panicles while in the field, G1-selection from the harvest and G2-selection from grains meant for food.

Seed selection methods	**Obs**	**Rank sum**
Control	4	20.50
G0	4	39.50
G1	4	18.00
G2	4	58.00

Chi-Squared=11.52 with 3 df, probability=0.009

Kruskall Wallis test for differences in V4-Electrical conductivity for the aged seeds in µScm-1g-1 among the following seed selection methods G0-selection of panicles

while in the field, G1-selection from the harvest and G2-selection from grains meant for food

Seed selection methods	Obs	Rank sum
Control	4	17.00
G0	4	47.00
G1	4	19.00
G2	4	53.00

Chi-Squared=11.52 with 3 df, probability=0.009

ANOVA table for testing for differences in V5-Seed health- % of infected seeds among the following seed selection methods G0-selection of panicles while in the field, G1-selection from the harvest and G2-selection from grains meant for food.

Analysis of variance

Source	SS	Df	MS	F	p-value
Between groups	2423.25	3	807.75	10.33	0.001
Within groups	938.50	12	78.21		
Total	3361.75	15	224.12		

APPENDIX VIII: ANOVA AND KRUSKAL WALLIS TEST FOR SEED PROCESSING METHODS

ANOVA table for testing for differences in moisture content in percentage among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh

Analysis of variance

Source	SS	Df	MS	F	p-value
Between groups	2.07	3	0.69	2.83	0.08
Within groups	2.92	12	0.24		
Total	5.00	15	0.33		

Kruskal Wallis test for differences in Analytical purity among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh

seed processing methods	Obs	Rank sum
Control	4	58.00
P0	4	10.00
P1	4	26.00
P2	4	42.00

Chi-Squared=14.12 with 3 df, probability=0.003

ANOVA table for testing for differences in seed germination of fresh seeds among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	7208.19	3	2402.73	181.62	0.000
Within groups	158.75	12	13.22		
Total	7366.94	15	491.13		

ANOVA table for testing for differences in V6-seed germination of the aged seeds among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	6850.19	3	2283.40	43.75	0.000
Within groups	626.25	12	52.18		
Total	7476.44	15	498.43		

ANOVA table for testing for differences V7-Germination index for fresh seeds among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	0.76	3	0.25	44.07	0.000
Within groups	0.07	12	0.01		
Total	0.83	15	0.06		

ANOVA table for testing for differences in V8-Germination index for aged seeds among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh

Analysis of variance

Source	SS	Df	MS	F	p-value
Between groups	0.87	3	0.29	45.22	0.000
Within groups	0.08	12	0.01		
Total	0.95	15	0.06		

Kruskal Wallis test for differences in V3-Electrical conductivity of the fresh seeds in µScm-1g-1 among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh.

seed processing methods	Obs	Rank sum
Control	4	10.00
P0	4	58.00
P1	4	35.00
P2	4	33.00

Chi-Squared=12.73 with 3 df, probability=0.005

Kruskall Wallis test for differences in V4-Electrical conductivity for the aged seeds in µScm-1g-1 among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh

seed processing methods	Obs	Rank sum
Control	4	10.00
P0	4	53.00
P1	4	33.00
P2	4	40.00

Chi-Squared=10.74 with 3 df, probability=0.013

ANOVA table for testing for differences in V5-Seed health- % of infected seeds among the following seed processing methods P0-thresh panicles immediately after harvest, P1-dry the harvest then thresh, P2-keep the harvest in a sack for some time then thresh

Analysis of variance

Source	SS	Df	MS	F	p-value
Between groups	7633.69	3	2544.56	122.26	0.000
Within groups	249.75	12	20.81		
Total	7883.44	15	525.56		

APPENDIX IX: ANOVA AND KRUSKAL WALLIS TEST FOR SEED STORAGE METHODS

ANOVA table for testing for differences in V1- moisture content in percentage among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place

Analysis of variance

Source	SS	Df	MS	F	p-value
Between groups	0.49	3	0.16	0.16	0.897
Within groups	9.91	12	0.83		
Total	10.39	15	0.69		

Kruskall Wallis test for differences in Analytical purity among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place

Seed storage methods	Obs	Rank sum
Control	4	58.00
S0	4	29.50
S1	4	37.00
S2	4	11.50

Chi-Squared=12.26 with 3 df, probability=0.007

ANOVA table for testing for differences in V2-seed germination among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	2943.69	3	981.23	82.20	0.000
Within groups	143.25	12	11.94		
Total	3086.94	15	205.80		

ANOVA table for testing for differences in V6-seed germination of the aged seeds among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	4388.50	3	1462.83	75.50	0.000
Within groups	232.50	12	19.38		
Total	4621.00	15	308.07		

ANOVA table for testing for differences in Germination index for fresh seeds among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place.

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	0.22	3	0.07	12.70	0.001
Within groups	0.07	12	0.01		
Total	0.28	15	0.02		

ANOVA table for testing for differences in Germination index for aged seeds among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place.

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	0.45	3	0.15	43.17	0.000
Within groups	0.04	12	0.003		
Total	0.49	15	0.03		

Kruskall Wallis test for differences in V3-Electrical conductivity of the fresh seeds in µScm-1g-1 among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place.

Seed storage methods	**Obs**	**Rank sum**
Control	4	16.00
S0	4	28.50
S1	4	33.50
S2	4	58.00

Chi-Squared=10.26 with 3 df, probability=0.016

Kruskal Wallis test for differences in V4-Electrical conductivity for the aged seeds in µScm-1g-1 among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place.

Seed storage methods	Obs	Rank sum
Control	4	12.00
S0	4	33.00
S1	4	37.00
S2	4	54.00

Chi-Squared=9.860 with 3 df, probability=0.020

ANOVA table for testing for differences in V5-Seed health- % of infected seeds among the following seed storage methods S0-store the seeds in tins, S1-store the seeds in sacks, S2-store the seeds above fire place.

Analysis of Variance

Source	SS	Df	MS	F	p-value
Between groups	7553.25	3	2517.75	38.51	0.000
Within groups	784.50	12	65.38		
Total	8337.75	15	555.85		