QUALITY OF FARM SAVED MAIZE (*Zea mays* L.) SEEDS IN BUSIA COUNTY AND ITS EFFECT ON INTENSITY OF FOLIAGE DISEASES

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(BSC CROP PRODUCTION, UNIVERSITE DE GOMA)

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DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION,
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UNIVERSITY OF NAIROBI

2018
DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other University.

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DEDICATION

I dedicate this thesis to my parents Mr. Nzanzu Kirarahumu Kyri and Mrs. Kavira Yalala Alphonsine, to my loving wife Mrs. Kahambu Yvette and in memory of our deceased son Chancelier Charles and to my siblings, I dedicate this work to you all for your support.
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# ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACB</td>
<td>African Centre for Biodiversity</td>
</tr>
<tr>
<td>AEZ</td>
<td>Agro-Ecological Zone</td>
</tr>
<tr>
<td>AGRA</td>
<td>Alliance for a Green Revolution in Africa</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>ASARECA</td>
<td>Association for Strengthening Agriculture Research in East and Southern Africa</td>
</tr>
<tr>
<td>CBOSG</td>
<td>Community-Based Organization Seed Grower</td>
</tr>
<tr>
<td>CBO</td>
<td>Community-Based Organization</td>
</tr>
<tr>
<td>COMESA</td>
<td>Common Markets for East and Southern Africa</td>
</tr>
<tr>
<td>CTA</td>
<td>Centre for Tropical Agriculture</td>
</tr>
<tr>
<td>DRC</td>
<td>Democratic Republic of Congo</td>
</tr>
<tr>
<td>DUS</td>
<td>Distinctness, Uniformity, and Stability</td>
</tr>
<tr>
<td>EASP</td>
<td>Ear aspect</td>
</tr>
<tr>
<td>ECA</td>
<td>East and Central Africa</td>
</tr>
<tr>
<td>ECAPAPA</td>
<td>East and Central Africa Program for Agriculture Policy Analysis</td>
</tr>
<tr>
<td>EPP</td>
<td>Ear per plant</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FIDA</td>
<td>Fonds International pour le Développement Agricole (International Fund for Agricultural Development)</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>GOK</td>
<td>Government of Kenya</td>
</tr>
<tr>
<td>GY</td>
<td>Grain Yield</td>
</tr>
<tr>
<td>IITA</td>
<td>International Institute for Tropical Agriculture</td>
</tr>
<tr>
<td>IRRI</td>
<td>International Rice Research Institute</td>
</tr>
<tr>
<td>ISTA</td>
<td>International Seed Testing Association</td>
</tr>
<tr>
<td>KALRO</td>
<td>Kenya Agriculture and Livestock Research Organization</td>
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<tr>
<td>KEPHIS</td>
<td>Kenya Plant Health Inspectorate Service</td>
</tr>
<tr>
<td>LM</td>
<td>Low Midland</td>
</tr>
<tr>
<td>LSD</td>
<td>Least Significant Difference</td>
</tr>
<tr>
<td>LVNWSB</td>
<td>Lake Victoria North Water Services Board</td>
</tr>
<tr>
<td>MOA</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>MLN</td>
<td>Maize Lethal Necrosis</td>
</tr>
<tr>
<td>MSV</td>
<td>Maize Streak Virus</td>
</tr>
<tr>
<td>NPT</td>
<td>National Performance Trial</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PDA</td>
<td>Potato Dextrose Agar</td>
</tr>
<tr>
<td>PASA</td>
<td>Partners for Seed in Africa</td>
</tr>
<tr>
<td>PLHT</td>
<td>Plant Height</td>
</tr>
<tr>
<td>PNUD</td>
<td>Programme des Nations Unies pour le Développement</td>
</tr>
<tr>
<td>RCBD</td>
<td>Randomized Complete Block Design</td>
</tr>
<tr>
<td>SADC</td>
<td>Southern Africa Development Community</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
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<tr>
<td>SEMIs</td>
<td>Seed Entreprise Management Institute</td>
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<tr>
<td>SSA</td>
<td>Sub-Saharan Africa</td>
</tr>
<tr>
<td>SSSA</td>
<td>Seed System Security Assessment</td>
</tr>
<tr>
<td>UMOA</td>
<td>Union économique et Monétaire Ouest-Africaine</td>
</tr>
<tr>
<td>UoN</td>
<td>University of Nairobi</td>
</tr>
<tr>
<td>UPOV</td>
<td>International Union for the Protection of New Plant Varieties</td>
</tr>
<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
</tr>
<tr>
<td>VCU</td>
<td>Value for Cultivation and Use</td>
</tr>
<tr>
<td>WW</td>
<td>Wet Weight</td>
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</table>
TABLE OF CONTENTS

DECLARATION ..................................................................................................................>Error! Bookmark not defined.

DEDICATION .................................................................................................................. ii

ACKNOWLEDGMENTS ..................................................................................................... iii

ACRONYMS AND ABBREVIATIONS ................................................................................ iv

TABLE OF CONTENTS ....................................................................................................... vii

LIST OF TABLES ............................................................................................................. xi

LIST OF FIGURES ............................................................................................................ xiii

APPENDICES ................................................................................................................... xiv

GENERAL ABSTRACT ...................................................................................................... xv

CHAPTER ONE: INTRODUCTION ..................................................................................... 1

1.1 Background information ............................................................................................. 1

1.2 Problem statement ....................................................................................................... 2

1.3 Justification .................................................................................................................. 4

1.4 Objectives .................................................................................................................... 4

1.5 Hypothesis ................................................................................................................... 5

CHAPTER TWO: LITERATURE REVIEW ......................................................................... 6

2.1 Maize production and its importance in East and Central Africa ................................ 6

2.2 Constraints to maize production in East and Central Africa ..................................... 8

2.3 Maize seed systems in East and Central Africa ......................................................... 10
2.4 Factors affecting seed quality ........................................................................................................ 14
2.5 Seed quality regulation and standards .......................................................................................... 16
2.6 Methods of evaluating seed quality .............................................................................................. 17

CHAPTER THREE ................................................................................................................................... 21
QUALITY OF RECYCLED MAIZE SEED IN BUSIA COUNTY OF WESTERN KENYA ... 21
3.1 Abstract ........................................................................................................................................ 21
3.2 Introduction .................................................................................................................................. 22
3.3 Materials and methods ................................................................................................................... 24
3.3.1 Description of the study area .................................................................................................... 24
3.3.2 Determination of quality of maize seeds in Busia County ......................................................... 24
3.3.3 Determination of physical purity of seed samples ..................................................................... 25
3.3.4 Determination of Germination and seedlings vigor ................................................................. 25
3.3.5 Determination of seed infections with disease causing pathogens ......................................... 26
3.3.6 Statistical data analysis ............................................................................................................ 27
3.4. Results ....................................................................................................................................... 27
3.4.1 Maize production practices ...................................................................................................... 27
3.4.2 Sources of maize seeds and seed storage methods ................................................................. 30
3.4.3 Management maize pests and diseases .................................................................................... 35
3.4.4 Physical purity of maize seed ................................................................................................... 37
3.4.5 Seed germination and seedling vigor of maize seed samples ................................................ 38
3.4.6 Infections of maize seed with disease causing pathogens ........................................... 41

3.5 Discussion .......................................................................................................................... 43

3.5.1 Maize production practices in Busia county ................................................................ 43

3.5.2 Quality of farmers’ maize seed in Busia County ............................................................ 47

CHAPTER FOUR .......................................................................................................................... 50

EFFECT OF RECYCLING MAIZE SEED ON FOLIAGE DISEASES ............................................ 50

4.1 Abstract .............................................................................................................................. 50

4.2 Introduction ......................................................................................................................... 51

4.3 Materials and methods ....................................................................................................... 52

4.3.1 Experimental design and layout .................................................................................. 52

4.3.2 Assessment of agronomic parameters ........................................................................ 53

4.3.3 Assessment of incidence and severity of foliage diseases .............................................. 54

4.3.4 Assessment of yield and yield components .................................................................. 54

4.3.5 Data analysis ................................................................................................................... 55

4.4 Results ................................................................................................................................ 55

4.4.1 Agronomic parameters ................................................................................................. 55

4.4.2 Incidence and severity of diseases ................................................................................ 57

4.4.3 Yield and yield components ......................................................................................... 61

4.5. Discussion ......................................................................................................................... 64

4.5.1 Emergence and plant lodging ...................................................................................... 64
4.5.2 Incidence and severity of diseases ................................................................. 65

4.2.3 Yield and yield components ........................................................................ 66

CHAPTER FIVE ............................................................................................................. 69

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS .............. 69

5.1 General discussion .................................................................................................. 69

5.2 Conclusion ............................................................................................................... 73

5.3 Recommendations .................................................................................................. 74

REFERENCES ............................................................................................................. 75

APPENDICES ............................................................................................................. 109
LIST OF TABLES

Table 1.1: Percentage of seed sources for major crops in Sub Saharan Africa in 2015........ 2
Table 2.1: Percentage seed sources by Country in East and Central Africa (ECA) in 2015........ 14
Table 3.1: Percentage of farmers who own various land size and acreage under maize production in two agro ecological zones of Busia County.................. 28
Table 3.2: Percentage of farmers who applied fertilizers to maize crop in two agro ecological zones in Busia County.................. 28
Table 3.3: Percentage maize seed sources in two agro ecological zones in Busia County in 2016.................. 30
Table 3.4: Percentage of farmers who gave reasons of not using certified maize seeds in the two agro ecological zones in Busia County.................. 31
Table 3.5: Percentage storage systems as applied by farmers in two agro ecological zones in Busia County.................. 33
Table 3.6: Percentage production in kilogram by seed sources in two agro ecological zones in Busia County (N=120).................. 35
Table 3.7: Percentage of farmers who reported pests in maize field in two agro ecological zones in Busia County.................. 36
Table 3.8: Percentage maize diseases reported by farmers in two agro ecological zones in Busia County.................. 36
Table 3.9: Percentage of farmers and applied diseases management in two agro ecological zones in Busia County.................. 37
Table 3.10: Percentage purity of maize seed from various sources in two agro ecological zones in Busia County during the long rain season 2017

Table 3.11: Germination and seedling vigour of maize seeds from various sources in two agro ecological zones in Busia County

Table 3.12: Percentage of Fungal genera isolated from maize seed sources in two Agro Ecological Zones in Busia

Table 4.1: Percentage emergence, dead and rotten seeds of different seed sources in Busia and Kakamega sites

Table 4.2: Percentage off types and plant lodging of the seed from various sources at Busia and Kakamega sites

Table 4.3: Incidence of seedling blight and Maize Sreak Virus of the seed sources at Busia and Kakamega sites

Table 4.4: Incidence of fungal diseases of seed sources in Busia and Kakamega sites

Table 4.5: Severity scores of fungal diseases of seed from the various sources in Busia and Kakamega sites

Table 4.6: Incidence and severity score of ear rot of the different seed sources in Busia and Kakamega sites

Table 4.7: Ear abnormalities percentage of seed from various sources in Busia and Kakamega sites

Table 4.8: Ear length and grain yield (kgha\(^{-1}\)) of various seed sources in Busia and Kakamega sites
LIST OF FIGURES

Figure 3.1: Percentage maize production in kg in two agro ecological zones in
Busia County .............................................................................................................. 29

Figure 3.2: Percentage maize utilization in two agro ecological zones in Busia
County (N=120) ........................................................................................................... 29

Figure 3.3: Awareness and use of certified maize seed in the two agro ecological
zones in Busia County in 2016.................................................................................. 31

Figure 3.4: Maize seed handling methods in two agro ecological zones in Busia
County ............................................................................................................................ 32

Figure 3.5: Maize seed sorting criteria using by farmers in the two agro
ecological zones in Busia County ............................................................................... 33

Figure 3.6: Percentage maize seed treatment methods in two agro ecological
zones in Busia County .................................................................................................. 34

Figure 3.7: Maize seed storage periods as applied by farmers in two agro
ecological zones of Busia County ............................................................................... 34

Figure 3.8: Applied pest management methods by maize producers in two agro
ecological zones in Busia County ............................................................................... 37

Figure 3.9: Percentage of infected maize seed from different seed sources in two
agro ecological zones in Busia County ........................................................................ 41
APPENDICES

Appendix 1: Survey questionnaire on maize production practices in Busia County of Western in March 2017

Appendix 2: Major diseases of maize observed from the various maize seed sources at Busia and Kakamega experiments

Appendix 3: Culture characteristics and their corresponding conidia view on microscope, isolated from maize seed from various sources in Busia County

Appendix 4: Maize vegetative growth stage diagram with critical period for production management practices

Appendix 5: Weather data for Kakame County during experimental period

Appendix 6: Weather data for Busia County during experimental period
GENERAL ABSTRACT

Farmer saved seed consists of inappropriate varieties, infected seeds of poor germination potential resulting in low seedling vigor, crop stand and high incidence of diseases leading to poor yield. The study was conducted to determine the quality of farmer-saved maize seeds in Busia County of western Kenya and the effect of seed quality on crop performance. A survey was conducted in two agro-ecological zones using a structured questionnaire to obtain information on sources of maize seed, production practices, awareness, constraint and availability of improved maize seeds. Maize seed samples were collected from farmers, local market, Agro vet shops and major seed distributors. The seed samples were analyzed for physical purity, germination, vigor, and infection with fungal seed-borne pathogens. The collected seeds were used for field evaluation trials at Busia and Kakamega Counties. The experiment was laid out in a randomized complete block design with three replicates. Data were collected on 50% emergence, plant and cob height, off types, ear aspect and abnormalities, the incidence of seedling blight and viral disease, incidence and severity of fungal diseases, yield and yield components. Data were subjected to analysis using SPSS and GenStat 15th Edition.

About 50% of smallholder farmers used own recycled maize seed from the previous season while other sources of seed are local markets, agro vet shops, government, and friends. Majority of the farmers are aware of improved maize varieties but the use of certified maize seed is low due to high cost. Armyworms and Striga were the major pests threatening maize production in the region but few farmers can afford chemical pesticides. Ear rot was reported as a major disease affecting maize and grain yield ranged between 200 and 600 kg per hectare. The maize seed samples from all the sources did not meet the Kenyan recommended purity threshold of 99% but seed from Distributors and Agro vet shops had high levels of purity. Farmer saved and local
market seeds had a poor physical purity which was below 70%. However, the seed samples had good germination and met the recommended standard of 90%. Farmer saved seed had the highest infection with 70.9% found to be contaminated. *Fusarium sp* was the common pathogen isolated from all sources. Others were *Aspergillus sp, Penicillium sp*.

Local market seeds had the highest field establishment. Farmer saved seeds had the highest number of off-type crops. Local market and farmer saved seeds had greater plant and cob height. There was no variation in root lodging between seed sources while farmer saved and local market seeds were highly susceptible to stalk lodging. Ear abnormalities were high in farmer saved and local market seeds which showed high incidence and severity of common diseases including northern leaf blight, gray leaf spot, Diplodia, rust, Brown spot, downy mildew and eyespot. Incidence and severity score of ear rot were high observed in farmer saved and local market seeds. However, agro vet seeds had the lowest incidence and severity of fungal diseases and performed with the highest yield depending on the variety.

Farmer saved seed is the predominant source of maize planting material but this seed is of inferior quality. Though informal seeds had high plant establishment, they were no true to their types, highly sensitive to lodging and infected by diseases. The certified maize seeds from agro vet shops were resistant to major diseases compared to the uncertified seeds and gave high grain yield. Farmers’ groups are heterogeneous differing in their preferences and priorities that should be considered in plant improvement programs. Farmers should be encouraged to use certified or improved varieties to enhance crop productivity. Farmers and Agro dealers should be trained and sensitized on the importance of using improved seeds by or through demonstration plots and open field days.

**Keywords**: Certified Seeds, Farmer saved seeds, Maize, Seed quality, Seed system
CHAPTER ONE: INTRODUCTION

1.1 Background information

Maize (Zea maize) is a cereal crop grown in different agro-climatic areas as a single crop or in intercropping. Maize is the basic diet in various nations (Rehman et al., 2002), the white maize is traditionally used as human food, consumed in different ways, and yellow maize for animal feed (Dredge, 2004). Maize is broadly utilized for livestock feed and raw material in the advanced nations while it is used as food for a household in the developing countries.

Maize grain is necessary for the diet of livestock and poultry due to the wide efficacies transformation of its dry matter to meat, milk, and eggs in comparison to other cereal crops (Badu et al., 2014). The entire maize plant is economically important: all parts are utilized for producing vast kinds of diet and non-diet output (Opaluwa, 2015). Nutritionally, the kernel is composed of 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar and 1.7% ash. Actually, maize constitutes the principle food for more than 85% of people in East and Central Africa (Nyoro et al., 2004).

In this region, 70% of the maize is produced by resource-poor farmers who frequently rely on import to supplement the local production (Mbithi, 2000). The major problem limiting developing countries to attain self-sufficiency in maize production is low yield per hectare (500kg/ha) compared to developed countries such as the USA, China whose production reached 307,386,000 MT in 2008/2009, accounting for 40% of the world maize production (Badu, 2014, Meng and Ekboir 2000). This situation is due to the low adoption of new agricultural techniques for example improved maize hybrid, fertilizers, uncertain seed quality from the informal system (ACB, 2015, Sperling, 2001).
1.2 Problem statement

The informal or traditional seed system also known as local system account for 60-97% of the bulk seeds in East and central Africa (ACB, 2015). Most of the seeds used by small-scale farmers, especially for pulses, millet, sorghum, indigenous vegetables, vegetative propagated and oil crops, are from informal system as illustrated in table1.1 (McGuire and Sperling, 2015; Sperling and McGuire, 2010, Chapoto and Jayne 2009; Dawit et al 2011; Tesfaye et al., 2012). Although maize appears as the most and well-organized component of agriculture, with most certified seed, the informal seed system remains predominant in this region. Farmer saved maize seed constitutes about 80% and certified seed constitutes less than 10% (McGuire and Sperling, 2016; ACB, 2015). The study from McGuire and Sperling (2016) showed specific crops for seed sourced from the informal system (Own stock, Friend, neighbor, relative, and local market) against certified seed used (Government, NGOs/UN agencies, Agro dealers, Community Base Seed Growers, Contract growers) summarized in Table 1.1.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Informal sources</th>
<th>Certified seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>81.7</td>
<td>18.3</td>
</tr>
<tr>
<td>Sorghum</td>
<td>91.6</td>
<td>7.6</td>
</tr>
<tr>
<td>Millet</td>
<td>84.4</td>
<td>15.6</td>
</tr>
<tr>
<td>Rice</td>
<td>89.4</td>
<td>10.6</td>
</tr>
<tr>
<td>Groundnut</td>
<td>92.9</td>
<td>7.1</td>
</tr>
<tr>
<td>Common bean</td>
<td>92.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Cassava</td>
<td>94.8</td>
<td>5.2</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>97.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Irish potato</td>
<td>97.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Source: McGuire and Sperling, 2016
The seed from informal system consists of inappropriate varieties, infected with various seed borne pathogens leading to poor germination potential and poor yield (Sperling, 2001). Poor seed quality results in defective seedling stands and more unhealthy plants in the field (IRRI 2013, FAO, 2009). Although East African research has boosted the implementation of the arrangement on harmonization of seed standards, regulations and procedures (Rohrbach et al., 2003; Minde and Waithaka, 2006; ECAPAPA, 2004), the adoption of improved maize seed varieties is low though new improved and adapted genotypes are available for increasing the farm outputs (Asea et al., 2014; Langyintuo et al., 2008).

In some countries of the East and Central Africa (ECA), such as Kenya, the seed industry is well organized with an important number of seed companies producing maize seed (ACB 2015; AGRA, 2013). Despite the effort to privatize the seed industry, the Kenyan government is still the major shareholder in the Kenya Seed Company (KSC) which is the predominant player in the Kenyan maize seed accounting for up to 90% of hybrid maize seed in the market (Andae, 2014; World Bank, 2013). Approximately, 90% of maize planting materials utilized by farmers are from the traditional system (CTA 2014; Badu et al 2014; Thijssen et al., 2008). Ali-Olubandwah (2011) reported also, that hesitate on the true maize material to utilize because of a great number of maize seed varieties from different companies in the region.

In the Democratic Republic of Congo, the seed industry is not developed. Producers operate without supervision on prevention of diseases (Tollen, 2011). Farmers recycling their own seeds remains common, whose quality status is not known and thus lead to a decline in yields, especially in North and South Kivu provinces (USAID, 2015). In August 2014, the Alliance for a Green Revolution in Africa through Partnership for Seed in Africa program (AGRA/PASA), introduced the project supporting the production of maize hybrid seed in North and south Kivu
provinces of Eastern DRC. In 2015, AGRA initiated and financed three private seed companies for quality seed Production. In addition, FIDA is supporting agriculture and one of the project components is maize production (FIDA, 2015).

1.3 Justification
Facilitating the small-scale agricultural producers to access high quality improved planting material is crucial for agriculture development and thus improves producers’ income (Mac, 2013). Seed or planting material is the basic input in any agricultural production (Tsedaley, 2015). It’s only by use of quality seeds that one can maximize on all the other inputs. Improving seed attributes improves the possible output of the material significantly (Atilaw, 2010). Use of high quality and clean seeds is likely to increase yields by 5-20% (Asea et al., 2010; Mew and Gonzales 2002). Seeds with improved attributes have the potential to increase the agricultural production up to 25-50% (CTA, 2014; Gebremedhim, et al., 2015). Facilitating the farmer to access seed that is free from diseases, with the acceptable viability of the plant species, available at the right time, responding to the ecological conditions is essential for producers to utilize their farm and expenses resources for great output anticipation (Sperling, 2001). Thus, critical assessment of maize production system especially the rate of adoption of good agronomic practices and improved seeds is necessary for food security, alleviating poverty and high output per hectare as well as appreciable returns to producers (Tahirou et al., 2009).

1.4 Objectives
The broad objective of the study was to contribute to increased maize productivity at smallholder farm level by use of quality seed.

The specific objectives were
To determine maize production practices and quality of Farm saved maize seed in Busia County of Western Kenya

To determine the effect of farm saved maize seed on intensity of foliage diseases.

1.5 Hypothesis

i. Farmer saved seed is the predominant source of maize seed in Busia County while it is of low quality, contaminated with disease-causing pathogens.

ii. The quality of maize seed has a great impact on the incidence and severity of diseases leading to reduced yield.
CHAPTER TWO: LITERATURE REVIEW

2.1 Maize production and its importance in East and Central Africa

Maize is an important crop that is adapted to a wide range of agro-ecological zones. It constitutes a principle diet for over 300 million people in Africa’s countries (Essiet, 2010). The last distinct type of maize to arrive in East Africa was the high altitude race Cuzco from Peru (Grobman et al., 1961). Currently, this crop is the most cultivated one for food and source of capital by growers in Africa (Smale et al., 2013).

Maize production in most of the continent’s regions is by Small-scale farmers who contribute for around 70% of maize (Mbithi, 2000). In 2008/2009, developed countries, such as USA and China, contributed 40% of the entire maize bulk in the world, producing an estimated 307,386,000 MT of maize. In comparison, the African regions, such as the ECA and sub-Saharan Africa the yields are as low as 500 kg ha\(^{-1}\) (Badu, 2014; Meng and Ekboir 2000).

In the East and Central African countries, such as Kenya, the first scientific maize research program began in 1955 in Kitale, the center for maize production in the White Highlands, with the first modern maize type released, Kitale Synthetic II which was based on inbred developed from the Kenya Flat White complex of farmers’ selections (Smale and Jayne, 2003). Maize is planted on 90% of all Kenyan farms and together with its commonly intercropped crop, beans occupies over 22% of all farmed land. In addition to being the major diet, maize is an economic resource for it generates capital and labor for the peasantry mainstream (Mbithi and Huylenbroeck, 2000). In terms of maize gains production and poverty reduction, Kenya is among the countries gaining most (La Rovere et al., 2014).

During the 1980s, the successful achievement in maize yield gains was from small-scale farmers who adopted new modern agriculture technology with the support of the government regulation
encouraging their consideration across outlet and costs supports (Smale et al., 2013). The large-scale farmer's maize producers in Kenya rarely operate on more than 40 ha (Kirimi et al., 2011). The report from Tegemeo Institute and East African Grain Council (EAGC) (2009) indicated that the national level of maize grain output decreased to 28.6% of total bags during 2008 and this was attributed to low investment and support to farmers by the government (Oluoch, 2011; MOA, 2006). This led to a fall of maize productivity that underwrote the financial activity and decreasing economic activities in the nation (USAID, 2011).

On the other hand, Maize is the first cereal crop in the D.R. Congo and has a huge importance for food supply for the Congolese population (Chauvin et al., 2012). The D.R. Congo’s main crops vary by region, though maize and cassava remain the major staples, and most areas support livestock production (FAO, 2013). Maize always tends to be grown on the better soils in the valley bottoms while cassava is mostly grown on the poorer, acid, sandy soils. Also, if a crop rotation is followed, maize always precedes cassava, and cassava always comes last in the rotation (USAID, 2011). Maize is grown in all provinces. There are no improved and adapted hybrids for DRC and farmers are not aware of fertilizer or herbicide use on their farms. The new agricultural technology is not used or it is unknown (Tollen, 2011).

Maize is produced by smallholder farmers, one ha or usually less per household, with no external inputs used. In smallholder agriculture, yields are very low, usually below 1,000 kg/ha (±800 kg/ha). This proves that few of them use improved techniques and mechanized technology, combined with limited economies of scale (Megan et al., 2015). In smallholder agriculture, all labor is manual, including harvesting and the shelling of the maize cobs (USAID, 2011). Small-scale proto-type farm is part of an association of 25 farmers, formed with the objective of reducing poverty by sharing knowledge and resources.
2.2 Constraints to maize production in East and Central Africa

Maize production has many constraints which prevent farmers from getting maximum yield. Poor soil fertility, weeds, pests and diseases, access to quality seeds and poor agronomic practices, weak or non-existent seed regulatory institutions are some of the production constraints of maize in African region (Ekasingh et al., 2004; Cairns, 2013; Ojo, 2000).

Soil fertility was identified among the major constraints to maize production associated with poor agronomic practices in Africa (Onyango et al., 2000; Mwangi et al., 1997). Most of these soils are acidic with deficiency in nitrogen and phosphorus. Majority of small scale farmers do not apply fertilizer to solve this deficiency problem. Those who use them usually did not follow the recommended fertilizer rates (Onyango et al., 2000).

Pests and diseases, all together cause direct yield losses ranged between 20 and 40%. (Savary et al., 2012, Oerke, 2006). The major pests includ stalk borer (*Chilo partellus*), african maize stem borer (*Buseola fusca*), fall armyworms (*Pseudaletia unipuncta*), grain weevils (*Sitophilus granaries*) and the Larger Grain Borer (*Prostephanus truncatus*), which causes postharvest losses in the range of 10 to 30%, depending on the year and location, although extremely high damage levels of up to 35% have been known to occur in maize storage in East and Central Africa (Infonet, 2010; Tripathi et al., 2011).

Noxious weeds such as *Striga hermonitca* is threating maize field in East and Central Africa countries. This weed existed since 1936 in Western Kenya (Khan et al., 2006) where it caused several problems including low maize yields (Woomer and Mulei, 2015). The destructive plant parasite of maize inhibits the plant growth by attaching itself to maize roots to draw the moisture and nutrient requirement and lead to poor yield and to some extent dead of the host plant (Ndwiga et al., 2013).
Some of the diseases affecting maize production include downy mildew (*Sclerophthora spp*), common rust (*Puccinia Sorghi*), turcicum leaf blight known as northern leaf blight (*Exserohilum turcicum*), grey leaf spot (*Cercospora zeae-maydis*), stalk rot and ear rots. Most of these diseases are transmitted by fungal pathogens carried by the seed itself or are soil borne. Common virus diseases affecting maize include maize streak virus (MSV) and maize lethal necrosis (MLN) (Tripathi et al., 2011; Wangai et al., 2012; CIMMYT, 2004). Maize yield loss inflicted by diseases varies by region and season. Generally, they influenced by the conditions of the environment, crop production practices, previous disease history, hybrid selection and susceptibility to disease (Munkvold and White, 2016; Wise et al., 2016). Yield loss due to maize diseases is estimated between 15 – 20% depending the disease and year (Munkvold and White, 2016; Mueller et al., 2016).

Seed is the major determinant of the upcoming plant growth. It constitutes the first key for crop production (Rita, 2009). Quality seed by itself contributes about 15-20% of the total production depending to the crop and it can be additionally rose up to 45% with efficient management of other inputs (Asif, 2016). Thus, quality seed is the basic determinant upon which all other inputs will depend for their full effectiveness (Krishibid, 2016). Non-adoption of improved varieties that are high yielding with potential resistance and tolerance to pests and diseases and abiotic stresses, farmer saving their own seeds or recycling their production for the next season is the major constraints in maize production (Badu et al., 2012). Real seed supply systems have the possibility to enhance crop output through timely and adequate supply of quality seed (FAO, 2012). There is necessity to enhance structural efficiency in seed marketing and providing information system on the market in West and Central Africa (IITA 2014).
The principle limiting factor to agricultural productivity in Africa has historically been a failure to provide farmers access to high yielding seed, without which little else done to assist them can have much effect (AGRA, 2017). In All crop production system, it is only the seed that sets the upper limit on what farmers can achieve (AGRA, 2017). The intensification of local farms and national food supply systems has been catalyzed by the introduction and distribution of seed of improved varieties with high yielding. While landraces crop varieties embody a number of traits that allow them to grow reliably under local conditions, they also, with few exceptions, embody very low yield potential. They lack the ability to respond to most improved crop management practices such as irrigation and fertilizers application. The most urgent priority for African agriculture is that governments in all African regions, donor agencies, research institutions and all concerned groups are to work together to ensure that Africa’s farmers have easier access to the right seed that can enable them to improve their production and thus, to enhance the level of their income (Lacoste et al., 2012; AGRA, 2017).

2.3 Maze seed systems in East and Central Africa

Seed system in East and Central Africa (ECA) is multi-structured, classified as formal, semi-formal and informal (ACB, 2015). Improving the traditional seed sector and enhanced relations to the public seed sector are critical (CTA 2014). The seed industry is composite and active, it is composed of the farmers’ system whereby farmers use their own seed saved from their harvest and the regulated system whereby the government and private institutions influence the seed multiplication and trading (MacRobert, 2013).

Lack of accessibility to seed by agriculture small-scale producers is a crucial factor that affects food security in most of African regions (COMESA, 2014). The regulation on variety testing and procedures for releasing seeds in these countries are considered as overlapped and stiff.
Hence, they are found to be difficult for commercialization of newly developed maize varieties (Setimela, 2009). The seeds go through standard and regulations which differ from country to country. The distinctiveness, uniformity, and stability (DUS) and the value for cultivation and use (VCU) tests are conducted for a variety to be admitted for commercialization (ECAPAPA, 2003).

For example, in Uganda, an on-farm trial is compulsory while in Kenya, the national performance trial is mandatory for variety release (Setimela et al., 2009). To meet the minimum requirement for varietal release, research institutions do breeding nurseries and evaluate the newly developed genotypes in National and Regional Performance (NRPT) for necessary agronomic data and yield performance for selecting the good variety to release (Wobil, 1998; Lanteri and Quagliotti, 1997). This was not adequate to speed up the process of releasing varieties for the benefit of small-scale farmers who rely on their local planting materials (Vivek et al., 2004).

Although the important investment in breeding research, the adoption of improved seeds in the region remain low, less than 10% (Langyintuo, 2009). In countries such as Kenya, Tanzania, and Zambia, the national seeds authority (NSA) assembles and conducts the national performance trial (NPT) which provides the data for value for cultivation and use (VCU). This test should be conducted for five to six sites or locations which make it expensive for a seed company to release a variety (Setimela et al., 2009).

Each country imposes its own standards that delay the process for introduction of improved variety and in addition of the cost for certification and testing requirement (Isaac, 2004). Regarding these issues, regional economic communities in Africa including Common Markets for East and Southern Africa (COMESA) and the Association for Strengthening Agriculture
Research in East and Southern Africa (ASARECA) discussed ways to harmonize regulations referring to the seed schemes of the Organization for Economic Cooperation and Development (OECD) and European Union (EU) (Isaac, 2004). The main goal of the harmonization of seed regulation was to enhance farmer access to quality seed at low cost.

For variety release, under the ECOWAS regulations, newly developed varieties need to be registered in one member Country to be eligible for trading in other country members whereas in COMESA and SADC, the variety should be registered in two member counties before it is allowed in the seed catalog of the region (Keyser, 2013). From ASARECA regulations, any variety released in another country’s national seed catalog will only require one year of domestic testing in the importing country before registration providing sufficient test data available from previous trial in identic agro-ecological zones (Keyser, 2013).

From harmonized seed regulations, certification procedures had been standardized to involve seed field inspection, seed processing, seed testing, labeling and sealing in East and Central Africa (Waithaka, 2012). The seed trade became easier, faster and less expensive. As result, in Kenya, before the harmonization, regulation process required that for DUS and VCU to be conducted before registration which test could take between one to three years before sufficient and necessary data are available for the variety to be registered in the seed catalog (Setimela, 2009). Thereafter harmonization, the testing period for new varieties has been shortened from three or more years to two seasons and the number of variety release committees has been reduced from three to two (Keyser, 2013). Many seed companies have been established, there are more than 100 seed companies registered by Kenya Plant Health Inspectorate Service (KEPHIS) to provide farmers with the quantity, quality and choice of seed to improve
agricultural output (Rohrbach, 2003; SADC, 2008; Mukuka, 2011; Waitaka et al., 2012; Giselquist et al., 2013; Poulton and Kanyinga, 2014).

East African countries have progressed in the implementation of the arrangement on harmonization of seed standards, regulations and procedures (Rohrbach et al., 2003, Minde and Waithaka, 2006; ECAPAPA, 2004), although the informal system account for 60 -80% of the planting material utilized by farmers, specifically for home-grown vegetable, legumes, potato, cassava, sorghum, and millet (ACB, 2015; McGuire and Sperling, 2016; Sperling and McGuire, 2010; and Chapoto and Jayne 2009). In some of these countries the seed industry is well organized, however, farm saved seed remains common (Table 2.1) (USAID, 2015; McGuire and Sperling, 2016).

Maize sector is the most monitored and certified in East and central Africa compared to other crops. Many seed companies exist, with improved plant varieties and potentially high yield and resistant to diverse climatic constraints (Makumbi, 2012), most of these seed companies grow maize seed, yet the adoption of improved maize seed varieties remains low, less than 10% (Langyintuo et al., 2008). Seeds from informal system occupy between 50 – 90 % of the maize seeds sown by small-scale maize producers (Sperling, 2001).

The informal or traditional seed system also known as local system is called informal because it is not regulated and is characterized by farmer-to-farmer seed exchange (Dawit et al., 2011, Tesfaye et al., 2012). It is semi-structured and operates mainly at the individual or community level (Chapoto and Jayne, 2009; CTA 2014; Badu et al., 2014; Thijssen et al., 2008). Farmer saved seeds have poor performance and are susceptible to pests and diseases, thus, gives low yield in contrast with the seed from the formal system (Zegeye et al., 2014; Alemu, 2015). Seeds from the informal system are easily available, low cost and have poor quality attributes. They are
inappropriate varieties, with infection, the seed quality attributes are below the standards limiting producers’ crop output (Sperling, 2001). In the formal seed system, the government is the main supporting system with several public institutions involved. Producers, companies and other seed dealers are registered and licensed to produce seed (Tesfaye et al., 2012). Seed from the formal sector are certified and of acceptable performance and their related productivity in term of yield and grain quality (CTA 2014; Sperling et al., 2013; Badu et al., 2014).

**Table 2.1:** Percentage seed sources by Country in East and Central Africa (ECA) in 2015

<table>
<thead>
<tr>
<th>Seed source</th>
<th>Malawi</th>
<th>Kenya</th>
<th>DRC</th>
<th>South Sudan</th>
<th>Zimbabwe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own stock</td>
<td>28.3</td>
<td>36.2</td>
<td>35.0</td>
<td>42.2</td>
<td>45.2</td>
</tr>
<tr>
<td>Community</td>
<td>7.8</td>
<td>5.7</td>
<td>16.9</td>
<td>12.1</td>
<td>21.9</td>
</tr>
<tr>
<td>Local market</td>
<td>32.0</td>
<td>40.1</td>
<td>44.6</td>
<td>34.3</td>
<td>9.9</td>
</tr>
<tr>
<td>Agro-dealers</td>
<td>17.5</td>
<td>11.6</td>
<td>0.4</td>
<td>0.2</td>
<td>5.8</td>
</tr>
<tr>
<td>CBSG</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Government</td>
<td>8.9</td>
<td>5.1</td>
<td>0.0</td>
<td>0.6</td>
<td>11.5</td>
</tr>
<tr>
<td>NGO</td>
<td>4.2</td>
<td>0.9</td>
<td>3.1</td>
<td>10.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Contracted growers</td>
<td>0.5</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Others</td>
<td>0.7</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

DRC = Democratic Republic of Congo, SBSG= Community Base Seed Growers, NGO= Non-Governmental Organizations (McGuire and Sperling, 2016)

### 2.4 Factors affecting seed quality

Seed quality refers to parameters that affect marketability (Moshatati, 2012) including varietal identity and purity for the new cultivar, integrity of the seed formation and water content, physiological, viability and vigor, and phytosanitary attributes, insects and seed-borne diseases (Caviness, 1978; Moshatati, 2012). Seed quality constitutes its varietal purity with high germination potential, free from disease causing pathogens (Mirza, 2015). Seed deterioration is determined by a number of factors including production methods, genetic make-up, occurrence
of pests and diseases, seed processing, seed storage methods, weather, soil condition and fertility among others (Basra, 2006; Mirza (2015).

Seed quality can be influenced by standard agronomic practices including planting conditions, sowing time, spacing, fertilizer dose, hoeing, weeding and plant protection measures, use of chemical, timing and methods of harvesting, threshing, drying and processing methods (Singh and Kumar, 2014, FAO, 2016b). Basra (1995) and Powell et al. (1985) reported that seeds produced under uncontrolled system result in poor quality, the carry the fungal seed borne and mycotoxin. Seed transmitted diseases constitute the main challenge in the world concerning seed dissemination. They are the main cause of poor performance of the crop from field emergence up to the yield (Du et al., 2001; Rajput et al., 2005; Niaz and Dawar, 2009; Paplomatas, 2006).

In deciding the location for seed production enterprises, a number of factors have to be taken into consideration. These include the genetic factors which are the genetic make-up, seed size and bulk density (IRRI 2013; FAO, 2004). Multiple studies had found that seed size, large or small have an effect on germination and yield in various conditions. Singh and Kailasanathan (1976) reported that large size wheat seeds lead to greater yield compared to small size seed when sown late. Seed size influences not only germination, emergence, and field establishment but also has an impact on biomass, yield and yield component (Baalbaki and Copeland, 1997; Nagaraju, 2001; Kumar and Seth, 2004; Stougaard and Xue, 2005; Dar et al., 2002). Broadly, large size seeds perform better in field than small size seed (Ambika et al., 2014). The bulk density of a grain is unrelated to its size but is related to its shape. The more slender the grain the less the bulk density (Kshirod, 2013). The significant aspect of seed and seed production depends on how a particular crop is pollinated and whether it is self-pollinated and cross-
pollinated or open pollinated or hybrid. Pollination affects plant varietal purity resulting in off-types (FAO, 2004).

Seed quality is affected by the physical or environmental factors including injury during planting, growing conditions during seed development, nutrition of the mother plant, physical damages during production or storage by machine and pests, moisture and temperature during storage and age or maturity of seeds (Mirza, 2015; Jordan et al., 1986; Abdullah et al., 2011), inflicting damages during plant growth even in stored maize bulk, and diseases are main limitations affecting maize production (Infonet-Biovision, 2013; Ekasingh et al., 2004). Seed quality is deteriorated depending on the moisture level at harvest and storage conditions (Ferreira et al., 2013). Seed storage is crucial for seed quality and suitability upkeep. It can have an impact on the whole feature of seeds quality attributes and contributes to seed ageing that decreases seed viability (Bennett and Klich, 2003). Seed goes through handlings from where it is produced to where it is processed and stored before moving to the final destination, moving from warehouse to farms. Through these operations, seed deterioration is inevitable but the rate can be minimized when attention is paid to storage temperature and moisture. These are the major factors affecting seed storage that affect the ability of the seed to germinate and their vigor whereas are they are the primary desired aim of seed handlers (Adetumbi and Olakoje, 2010).

2.5 Seed quality regulation and standards

Multiple international organizations, conventions and treaties work on the regulations of seed trade, starting from access to delivery of quality seeds to farmers (OECD, 2012). These organizations provide an international regulatory framework for the benefits of breeders, farmers and the consumers of the end product. Some of these organizations include the
Organization for Economic Co-operation and Development (OECD) which provides regulations focusing mainly on the distinctiveness, uniformity and stability, the value for cultivation and use of newly developed variety. The International Union for the Protection of New Plant Variety (UPOV) which aims is to encourage development of new plant variety for the benefit of producers. It guarantees plant breeders right for the variety that respond to the DUS and VCU tests (OECD, 2012). The International Seed Testing Association (ISTA) which provides standards for seed quality testing (ISTA, 2015, OECD, 2012).

In ECA, as by the COMESA seed trade harmonization regulations, the recommended field standards are previous cropping season 1, isolation for certified OPVs and hybrids 200m, maximum off-types for OPVs 0.5% and for hybrids 0.2%, minimum field inspections 3 for both categories. Laboratory standards include minimum germination for OPVs and hybrids 90%, minimum pure seed 99% and maximum moisture content 13% (COMESA, 2014). Countries in the region establish their seeds regulations and standards based on the pre-established international standards from cited organizations (Kenya Low Reports, 2012). For example, the Kenya seeds and plant varieties Act, Cap 326 regulated by KEPHIS, the maize field standards are carried out as per the OECD, OPV field isolation 200m, off-types 0.5%, inspection minimum 2. Concerning hybrid maize, field isolation 200m, maximum off-types 1, and inspection minimum 3. The laboratory seed tests and analysis are carried out as per the ISTA standards. Both OPVs and hybrid maize, the recommended pure seed is 99%, minimum inert matter 0.95%, maximum other seed 0.05%, minimum germination 90% (Sikinyi, 2010).

2.6 Methods of evaluating seed quality

The most important components of seed quality are cultivar purity, analytical purity, germination, seed vigor, seed health and moisture content (ISTA, 2015; Douglas, 2005).
Evaluation of quality attributes of the seed starts from field inspection of the growing crop for it genetic purity and various methods in the laboratory defined by ISTA providing standards that are periodically updated in light of new scientific evidence (ISTA, 2015; FAO, 2012).

Seed testing provides information in order to meet legal standards (Basra, 2006), and establishes the rate of sowing for a given stand of seedlings (Doijode, 2006). A high-quality seed lot is a function of the characteristics, seed quality attributes that are routinely tested by seed companies or private and state seed laboratories (Perkins and Cantiliffe, 1984; FAO, 2004). Tests that are routinely conducted in seed testing laboratories include physical purity, germination, and vigor. Seed health is determined to find the level of infection by seed borne pathogens.

The genetic purity of the seed is evaluated by the distinctiveness, uniformity, and stability (DUS test) and the value for cultivation and use (VCU) for its response to its trueness to type of the variety and of homogeneity in the field during development (OECD, 2012; IRRI, 2013). The seedling/plant emerging from the seed should look like to its mother plant in all aspects. This quality feature is necessary for the desired goal of which the variety was bred for, it could be yield or resistance to various stresses (OECD, 2012). The examination generates a description of the variety such as plant height, leaf shape, time of flowering, tassel appearance and color (Nyamwanya, 2015).

The physical purity test is conducted to determine different parameters including pure seeds, inert matter, weed seeds, insect damage, shriveled seeds, discolored seeds (FAO, 2010; ISTA, 2015). The purity examination determines the percentages by weight of each component in a sample. In the international trade, this examination is used mostly to control the presence of seeds of harmful or unwanted species (Florida, 2017).
Germination test is done to determine what proportion of seeds in an accession will germinate under satisfactory conditions and produce normal seedlings, seedlings that have all structures including roots, shoots and sufficient food reserves, able to develop into reproductively mature plants (ISTA, 2015). To assess the germination, different methods are proposed by international organizations, these methods include sand method (S). Seed to be tested are placed on or in sterilized sand. While using paper, in this case two methods are used: either on top of layers towel paper (TP) or between papers (BP). The germination room condition recommended is between 20-30°C. Evaluation count starts the fourth day from seed planting. Different components are evaluated through germination test. These parameters include germinated seeds, normal seedlings, hard seeds, fresh seeds, abnormal seedlings and dead seeds reported in percentage of the total number of the seeds tested. Germination percentage can indicate the seed vigor and it predicts field establishment (ISTA, 2015; IRRI, 2013).

Seed vigor consists of the capacity of seed to arise from the soil and live under potentially stressful field conditions and to grow rapidly under favorable environments. Seed vigor indicates the difference in physiological potential between the different seed samples in aim to clarify the seed lot that has higher probability to perform well in the field (Finch and Bassel, 2015; Mahender et al., 2015). There are different categories of vigor test methods. The stress tests consist of cold, accelerated ageing and controlled deterioration tests. The biochemical tests include conductivity and tetrazolium tests. The third method is seedling growth and evaluation tests. Seedling growth and evaluation test consists of several tests based on seedling performance. This study emphasized on two tests methods including speed of germination and uniform seedling emergence. The speed of germination is determined by the first count of germinated seed over the specific day count from when the seed was planted. Uniform seedling
emergence is determined by measuring seedling length or seedling dry weight (FAO, 2016b; ISTA, 2015, Marcos, 2015).

Seed health tests methods depend on the organism being tested for and the purpose of the test quality assurance or phytosanitary purposes when the seed is exported (ISTA, 2009). These include visual examination of seeds externally or internally, macro or microscopically for the presence of pathogens as well as incubating seeds on agar or moist blotter papers and identifying the pathogens microscopically (Warham et al., 1990). Many detection assays exist for different seed borne pathogens. However, few satisfy the minimum requirements for adequate seed tests. Ideally, seed assays should be sensitive, specific, rapid, robust, inexpensive and simple to implement and interpret (Walcott, 2003). Agar plate method is the most used for seed-borne fungus. Even at preliminary phase of development, it is possible with the incubation method to detect viable fungus material. Generally, agar plate method is done by plating seeds on sterilized agar media including potato dextrose agar (PDA) or malt agar for seed borne fungi growth while incubated for seven to ten (7-10) days with alternating 12 hours light and 12 hours darkness (Tsedaley, 2015; Islam et al., 2000; Wareham et al., 1996, IRRI, 1994).
CHAPTER THREE
QUALITY OF FARM SAVED MAIZE (*Zea mays* L.) SEED IN BUSIA COUNTY OF WESTERN KENYA

3.1 Abstract

Farmer saved seed consist of inappropriate varieties, infected seeds of poor germination potential resulting in low seedling vigor, crop stand and high incidence of pests and diseases leading to poor yield. The study was conducted to determine the quality and field emergence of maize seeds in Busia County. Survey was conducted in two agro ecological zones using structured questionnaire to obtain information on sources of maize seed, production practices, and awareness of certified maize seeds, constraint and availability of improved maize seeds. Maize seed samples were collected from farmers, local market, agro vet shops and major seed distributors. The seed samples were analyzed for physical purity, germination, vigor and seed health. Germination was determined by paper towel method while seed health test was conducted using agar plate method. The study showed that maize is mainly produced by small scale farmers on farms less than two hectares and 50% of the farmers use own recycled seed. Though awareness on improved maize varieties is high, few farmers use certified maize seed. Ear rot was the major disease and grain yield ranged between 200 and 600 kg per hectare. Seed purity was below the 99% legislated limit but the seeds met the recommended germination standard of 90%. Farmer saved seed was contaminated with diseases pathogens mainly *Fusarium sp, Aspergillus sp* and *Penicillium sp* by up to 70.9%. Recycled maize seeds are of poor quality, infected by diseases causing pathogens that affect negatively crop production. Therefore, farmers should be encouraged to use certified or improved seeds to enhance maize productivity.

**Key words:** Farmer saved seed, maize, seed quality, seed system
3.2 Introduction

Maize constitutes the principle food for more than 85% household in Kenya (Nyoro et al., 2004). In the country, more than 38% of agriculture actors produce maize (GOK, 2003). Small scale farmers count for 70% of maize production (Export Processing Zone Authority, 2005). The crop is mostly for subsistence, holding between 50 – 70% of the total food production (Mbithi, 2000). Maize yield in the region is between 500kg to 1500kg per hectare (Badu et al., 2014).

Maize production has numerous limitations preventing producers from attaining full production potential. Low quality seed, poor soil fertility, high cost of labor, pests, diseases, poor agronomic practices, among others, are some of the problems limiting maize production (Ekasingh et al., 2004; Meissle et al., 2010; Mahuku et al., 2015; Infonet-Biovision, 2013). Pests inflicting damage during plant growth even in stored maize bulk, and diseases are main limitations affecting maize production (Infonet-Biovision, 2013). Adoption of improved maize hybrid varieties is very low, while qualified to be resistant and tolerant to pests, diseases and abiotic stresses, farmer saved seed is the predominant source of planting material (Badu et al., 2012; Badu et al., 2014).

Farmer saved maize seeds constitute about 80% in East and Central Africa. Though maize sector appears the most organized with numerous certified varieties from different seed companies, the use of certified maize seeds still low, less than 10% (McGuire and Sperling, 2016; ACB, 2015). Farmer saved seeds are of inappropriate varieties, infected seeds of poor quality attributes and of poor yield (Sperling, 2001). The Kenyan seed industry is well organized, with a quite number, more of seed companies producing maize hybrid seeds (ACB, 2015; AGRA, 2013). However, small scale farmers continue to recycle maize grain from previous season production.
Approximately 90% of maize planting materials are from informal system (CTA, 2014; Badu et al., 2014; Thijssen et al., 2008).

Basra (1995) and Powell et al., (1985) indicated that farmer saved seeds are produced under uncontrolled system, as consequence, they result in poor quality with high level of infection with seed borne diseases. Seed transmitted diseases constitute the main challenge in the world concerning seed dissemination, being the highest cause of poor performance of the crop from field emergence up to the yield (Van Du et al., 2001, Rajput et al., 2005; Niaz and Dawar, 2009; Paplomatas, 2006). The rate of seed deterioration is determined by a number of factors such as kind or variety of the seed, storage, temperature, relative humidity, seed moisture content, biological factors including fungi that create their own biological niche (Basra, 2006, Bhatia et al., 2010; Ghassemi et al., 2010). Bennett and Klich (2003) observed that seed storage is crucial for seed quality. It can have impact on the whole feature of seeds quality attributes and contributes to seed ageing that decreases seed viability. The significant aspect of seed and seed production depends on how a particular crop is pollinated and whether it is self-pollinated and cross-pollinated or open pollinated or hybrid (FAO, 2004).

Tahiru et al. (2009) indicated that good agronomic practices in association with use of improved varieties are the way to enhance production and food security, thus alleviating poverty. Famers recycling their own on farmer saved seeds of unknown quality lead to spread of noxious weeds leading to decline in yields (USAID, 2015). Facilitating farmer accessing disease free seeds of high viability of wanted plant species is essential for producers to utilize their farm and expenses resources for great output anticipation (Sperling, 2001). This study aimed to determine the production practices and quality of farmers’ maize seeds in Busia county of Western Kenya.
3.3 Materials and methods

3.3.1 Description of the study area

Busia County covers about 1261.3 km², located at 60°1’N to 00°27’23”N and 34°01’18”E to
34°021’E, it borders Bungoma county to the North, Siaya County to the South and to the West
the Republic of Uganda. The average temperature is of 22°C and between 750mm and 1,800mm
of rain per year (Stephen et al., 2011). The dominant agro-ecological zone is lower midlands
(LM) with about four distinct subzones that support different agricultural activities. These
subzones are LM1, LM2, LM3 and LM4 which represent sugarcane, marginal sugarcane, cotton
and marginal cotton zones. The soils are generally acrisols. The main source of livelihood is
farming for subsistence and petty trade (Stephen et al., 2011). The active agricultural population
of the county is estimated to 111,345 with 13,826 households (Stephen et al., 2011).

3.3.2 Determination of quality of maize seeds in Busia County

A field survey was conducted during the short rain season of 2016. The study was conducted
using a multistage stratified sampling design as described by Lovric (2010). Two Agro
Ecological Zones were selected; LM1 and LM2 sub AEZ as described by Ali-Olubandwah et al.
(2010), Ali-Olubandwah et al. (2011) and Mudavadi et al. (2001). Maize grower Farmers was
interviewed using semi structured questionnaire in Appendix 1 to obtain information on maize
seed source, awareness, availability and affordability of improved maize seeds, the challenges
faced in the production. The sample size was obtained using the formula below as described by
Barrett et al. (2011).

\[ n = \frac{N}{(1+N(e)^2)2} \]
Where \( n \) is the sample size, \( N \) the population size assuming 95% level of confidence, \( P = 0.5 \) and the margin of error \( (e) \) is 0.1.

About 76 maize seed samples were collected from maize producer households and local market and eight samples from Agro vet in each agro ecological zone. Other four samples were obtained from major seed distributors. All the material collected was subjected to laboratory analysis for seed quality. Samples for routine tests were stored in botany laboratory and the portion for seed health test was stored in the fridge in pathology laboratory before analysis.

### 3.3.3 Determination of physical purity of seed samples

Physical purity test was done to separate the pure seeds, inert matter, weed seeds, insect damage and shriveled seeds content in the sample as described by ISTA (2015). Samples were well mixed to get homogeneity and a representative sample was taken for analysis and 400g was divided into four replicates of 100g each. Seeds were placed on a white manila paper and separated into pure seeds, other crop seeds, inert matter weed seeds, and insect damage seeds, shriveled and discolored seeds using a forceps. Each fraction from each replicate was weighed separately and the percentage calculated as follows:

\[
\text{Component (\%)} = \frac{\text{Component weight} \times 100}{\text{Total seed weight}}
\]

### 3.3.4 Determination of Germination and seedlings vigor

Germination test was carried out using the paper towel method described by ISTA (2015) using 400 seeds in four replicate of 100 seeds from each seed sample. The seeds were surface sterilized in 2% sodium hypochlorite for 3 minutes, and washed off in 3 changes of sterile distilled water and dried on sterile paper towel (ISTA, 2015, Warham et al., 1996). Three layers
of absorbent paper towel were placed in a sandwich box, moistened with sterile distilled water and the seeds were placed on the paper towel. Two layers of wet paper towels were placed on top of the seeds. The boxes closed and the seeds incubated under source of natural light. The number of germinated seeds was counted at 6, 9 and 12 days after planting. After 12 days, the seedlings were evaluated and the numbers of normal seedlings, abnormal seedlings, infected seedlings, hard seeds and moldy seeds in each replicate of 100 seeds (ISTA 2015). Germination percentage and germination index were calculated as:

\[
\text{Germination (\%) = } \frac{\text{Germinated} \times 100}{\text{Number of the seed on tray}}
\]

\[
\text{Germination index} = \frac{\text{GS 1st count}}{\text{Days of 1st count}} + \frac{\text{GS 2nd count}}{\text{Days of 2nd count}} + \frac{\text{GS 3rd count}}{\text{Days of 3d count}}
\]

Where GS stands for germinated seeds.

Pure Live Seeds (PLS) was calculated to determine viable seeds with germination potentiality (USAID, 2009; Islam et al., 2012).

\[
\text{PLS} = \text{Germination percentage} \times \text{Percentage Pure seed}
\]

Seedling Vigor index was determined as described by Marcos (2015) as:

\[
\text{Seedling Vigor Index I} = \text{Germinate\%} \times \text{Seedling length}
\]

\[
\text{Seedling Vigor Index} = \text{Germinate\%} \times \text{Dry weight}
\]

**3.3.5 Determination of seed infections with disease causing pathogens**

Infection of the seed with fungal disease-causing pathogens was determined by using the Agar plate method. Seeds were surface sterilized in 2% sodium hypochlorite for 2 to 3 minutes and rinsed in three changes of sterile distilled water. The seeds were aseptically plated on Potato
Dextrose Agar (PDA) amended with antibiotic to constrain bacteria growth. Five seeds were plated on the molten media in each plate and a total of 40 seeds were plated for each sample. The plates were incubated for 7 to 10 days with alternating 12 hours light and 12 hours darkness (Islam et al., 2000; Wareham et al., 1996, IRRI, 1994). The number of infected seeds in each Petri dish was counted and recorded in a data sheet as this was used to determine the percentage seed infection. Each of the fungi presented was then be sub-cultured on fresh potato dextrose agar (PDA) to identify the cultural characteristics.

Since different fungal colonies were formed on the agar, the most common appearing colony was identified. Examination was done both visually and microscopically. Slides of the fungal growth were prepared and observed under a microscope and fungi were identified on the basis of their typical structure and basic characteristics including mycelium type, colony size, color (Barnett and Hunter, 1972; Bhale et al., 2001).

3.3.6 Statistical data analysis

The survey data was analyzed using statistical software. The survey data was analyzed using SPSS 20.0 and experiment Data collected was subjected to analysis of variance (ANOVA) using GENSTAT 15th edition. Mean was separated using Fisher’s protected LSD at 0.05 confidences.

3.4. Results

3.4.1 Maize production practices

Land distribution varied within the two Agro ecological zones with majority of farmers owning land of which size ranged between 0.5 – 1.5 hectare (Table 3.1). Most of interviewed farmers produced maize on farm sizes of about 0.5ha. In both sites, the majority of farmers utilized farmyard manure while others simultaneously used the compost and the Diammonium Phosphate (DAP) or the Diammonium Phosphate itself as basal fertilizer (Table 3.2). Maize yields in both
agro-ecological zones ranged between 200 and 600 kg per ha, but a few farmers harvested over 2000kg/ha (Figure 3.1). Farmers cultivate maize mainly for subsistence and market and it is the main crop in both agro ecological zones of Busia county with 80% and 95%, respectively in LM1 and LM2 (Figure 3.2).

**Table 3.1:** Percentage of farmers who own various land size and acreage under maize production in two agro ecological zones of Busia County

<table>
<thead>
<tr>
<th>Farm (ha)</th>
<th>Land size</th>
<th>Maize plot</th>
<th>Land size</th>
<th>Maize Plot</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤0.5</td>
<td>16.7</td>
<td>76.7</td>
<td>23.3</td>
<td>73.3</td>
<td>20.0</td>
</tr>
<tr>
<td>0.5 - 1.5</td>
<td>71.7</td>
<td>23.3</td>
<td>55</td>
<td>25</td>
<td>63.4</td>
</tr>
<tr>
<td>1.5 - 3</td>
<td>11.7</td>
<td>0.0</td>
<td>16.7</td>
<td>1.7</td>
<td>14.2</td>
</tr>
<tr>
<td>&gt;3</td>
<td>0.0</td>
<td>0.0</td>
<td>5.0</td>
<td>5.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

**Table 3.2:** Percentage of farmers who applied fertilizers to maize crop in two agro ecological zones in Busia County

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Lower Midland Zone 1</th>
<th>Lower Midland Zone 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm yard manure</td>
<td>41.7</td>
<td>38.3</td>
</tr>
<tr>
<td>Compost and DAP</td>
<td>30.0</td>
<td>36.7</td>
</tr>
<tr>
<td>DAP</td>
<td>26.7</td>
<td>25.0</td>
</tr>
<tr>
<td>Mavuno</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td>No Application</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Figure 3.1: Percentage maize production in kg in two agro ecological zones in Busia County

Figure 3.2: Percentage maize utilization in two agro ecological zones in Busia County (N=120)
3.4.2 Sources of maize seeds and seed storage methods

The majority of farmers used own maize seeds with only 20.8% of farmers obtaining seeds from agrovet shops. Very few farmers get the see from local market. In the agro ecological zone LM1, 36.7% of the farmers recycled their seeds and 28.3 bought from Agro vet shops while in agro ecological zone LM2, 60% of farmers used farmer saved seeds. Only 13.3% of farmers used certified seed from Agrovet (Table 3.3).

Table 3.3: Percentage maize seed sources in two agro ecological zones in Busia County in 2016

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Lower Midland Zone 1</th>
<th>Lower Midland Zone 2</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own saved</td>
<td>36.7</td>
<td>60.0</td>
<td>48.4</td>
</tr>
<tr>
<td>Agro vet</td>
<td>28.3</td>
<td>13.3</td>
<td>20.8</td>
</tr>
<tr>
<td>MP/Government</td>
<td>21.7</td>
<td>8.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Local market</td>
<td>11.7</td>
<td>18.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Friend</td>
<td>1.7</td>
<td>0.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>

All the farmers interviewed are aware of the improved certified maize seed but the use of certified seed is low (Figure 3.3). Majority of farmers have refrained from giving their reason of not using the certified maize seed, but others expressed respectively that the certified seed is expensive, not different from their own variety (Landraces). Farmers in LM2 indicated that the certified maize variety was not good for meal (Table 3.4).

Maize seed handling varied from the two agro ecological zones. Majority of the farmers in agro ecological zone LM1 (50%) get packed maize seeds from agro vet shops others select the seed from mid grain on cob while in agro ecological zone LM2 the majority (50%) select the seed from mid grain on cob to prepare the seed, 21.7% get packed seed from agro vet shops. Few
farmers in both agro ecological zones shell the whole maize cob followed by sorting to prepare the seed (Figure 3.4).

Figure 3.3: Awareness and use of certified maize seed in the two agro ecological zones in Busia County in 2016

Table 3.4: Percentage of farmers who gave reasons of not using certified maize seeds in the two agro ecological zones in Busia County

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Low Midland Zone 1</th>
<th>Low Midland Zone 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expensive</td>
<td>23.3</td>
<td>28.3</td>
</tr>
<tr>
<td>Not different from our variety</td>
<td>16.7</td>
<td>18.3</td>
</tr>
<tr>
<td>Not good for meal</td>
<td>1.7</td>
<td>20.0</td>
</tr>
<tr>
<td>Untrusted variety</td>
<td>9.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Nothing to report</td>
<td>43.3</td>
<td>28.3</td>
</tr>
</tbody>
</table>
Criteria used by farmers in selecting the seed included large healthy grain from the middle of the cob (Figure 3.5). Majority of farmers did not store the seeds bought from agro vet shops and market but planted the seeds directly. The common methods of storing seeds as cited by farmers are in sacs, basket plastic containers, hanging over the fireplace (Table 3.5). The seeds obtained from agro vet shops and seed dealers come treated but the farmers who selected own seeds treated it with Actelic dust and or wood ash during storage (Figure 3.6). The duration of storing the seeds varied from 2 – 9 months (Figure 3.7). The farmers reported that certified seeds from agro vet gave high yields of up to 2000 Kg/ha while the farmer saved seed gave yield of 200 – 600 Kg/ha (Table 3.6).

Figure 3.4: Maize seed handling methods in two agro ecological zones in Busia County
Table 3.5: Percentage storage systems as applied by farmers in two agro ecological zones in Busia County

<table>
<thead>
<tr>
<th>N=120</th>
<th>Storage methods</th>
<th>Lower Midland Zone 1</th>
<th>Lower Midland Zone 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Buy and plant</td>
<td>56.7</td>
<td>31.7</td>
</tr>
<tr>
<td></td>
<td>Sac storage on floor</td>
<td>11.7</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>Sac storage on palette</td>
<td>8.3</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Hanging with husks over fireplace</td>
<td>6.7</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>Basket</td>
<td>15.0</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>Plastic container</td>
<td>1.7</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Figure 3.5: Maize seed sorting criteria using by farmers in the two agro ecological zones in Busia County
Figure 3. 6: Percentage maize seed treatment methods in two agro ecological zones in Busia County

Figure 3. 7: Maize seed storage periods as applied by farmers in two agro ecological zones of Busia County
Table 3.6: Percentage production in kilogram by seed sources in two agro ecological zones in Busia County (N=120)

<table>
<thead>
<tr>
<th>Production kg/ha</th>
<th>Agro vet</th>
<th>Own saved</th>
<th>Local market</th>
<th>MP/Government</th>
<th>Friend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Midland Zone I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-200</td>
<td>1.7</td>
<td>13.3</td>
<td>0.0</td>
<td>3.3</td>
<td>0.0</td>
</tr>
<tr>
<td>200-600</td>
<td>0.0</td>
<td>23.3</td>
<td>11.7</td>
<td>6.7</td>
<td>1.7</td>
</tr>
<tr>
<td>600-1000</td>
<td>3.3</td>
<td>0.0</td>
<td>0.0</td>
<td>3.3</td>
<td>0.0</td>
</tr>
<tr>
<td>1000-2000</td>
<td>5.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td>&gt;2000</td>
<td>18.3</td>
<td>0.0</td>
<td>0.0</td>
<td>6.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lower Midland Zone II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-200</td>
<td>3.3</td>
<td>8.3</td>
<td>5.0</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td>200-600</td>
<td>1.7</td>
<td>43.3</td>
<td>8.3</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td>600-1000</td>
<td>0.0</td>
<td>5.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1000-2000</td>
<td>3.3</td>
<td>1.7</td>
<td>5.0</td>
<td>3.3</td>
<td>0.0</td>
</tr>
<tr>
<td>&gt;2000</td>
<td>5.0</td>
<td>1.7</td>
<td>0.0</td>
<td>1.7</td>
<td>0.0</td>
</tr>
</tbody>
</table>

3.4.3 Management maize pests and diseases

The major pests reported by farmers in both agro ecological zones were armyworms, striga, cutworms, termites and stalk borers (Table 3.7) while the diseases were ear rot, head smut, maize streak, maize lethal necrosis, nutrient deficiency and seedling blight (Table 3.8). Farmers adopted varied techniques to manage pests, including weeding, application of soap diluted in tap water. However, very few farmers applied pesticides to fight pests in their maize field (Figure 3.8). Farmers corrected nutrient deficiency by applying CAN or by uprooting plants showing symptoms (Table 3.9)
Table 3.7: Percentage of farmers who reported pests in maize field in two agro ecological zones in Busia County

<table>
<thead>
<tr>
<th>Pests</th>
<th>Lower Midland Zone 1</th>
<th>Lower Midland Zone 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armyworms</td>
<td>43.4</td>
<td>46.7</td>
</tr>
<tr>
<td>Striga</td>
<td>21.7</td>
<td>20.0</td>
</tr>
<tr>
<td>Cutworms</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Termites</td>
<td>8.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Stalk Borers</td>
<td>8.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Nothing to report</td>
<td>8.3</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Table 3.8: Percentage maize diseases reported by farmers in two agro ecological zones in Busia County

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Lower Midland Zone 1</th>
<th>Lower Midland Zone 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear rot</td>
<td>31.7</td>
<td>16.7</td>
</tr>
<tr>
<td>Nutrient deficiency</td>
<td>30.0</td>
<td>18.3</td>
</tr>
<tr>
<td>Head smut</td>
<td>10.0</td>
<td>6.7</td>
</tr>
<tr>
<td>Maize streak virus</td>
<td>8.3</td>
<td>18.3</td>
</tr>
<tr>
<td>Maize lethal necrosis</td>
<td>6.7</td>
<td>10.0</td>
</tr>
<tr>
<td>Seedling blight</td>
<td>1.7</td>
<td>23.3</td>
</tr>
<tr>
<td>Nothing to report</td>
<td>11.6</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Figure 3.8: Applied pest management methods by maize producers in two agro ecological zones in Busia County

Table 3.9: Percentage of farmers and applied diseases management in two agro ecological zones in Busia County

<table>
<thead>
<tr>
<th>Management</th>
<th>Lower Midland Zone 1</th>
<th>Lower Midland Zone 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of CAN</td>
<td>10.0</td>
<td>5</td>
</tr>
<tr>
<td>Farmyard manure and DAP</td>
<td>1.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Uprooting</td>
<td>5</td>
<td>18.3</td>
</tr>
<tr>
<td>No Application</td>
<td>83.3</td>
<td>73.3</td>
</tr>
</tbody>
</table>

CAN: Calcium ammonium nitrate, DAP: diammonium phosphate

3.4.4 Physical purity of maize seed

The physical purity showed variation in pure seeds, other variety, inert matter, shriveled and damaged seeds in both agro ecological zones of Busia County. Pure seeds significantly varied (p≤0.05) among the zones and the seeds from different sources. In agro ecological zone 1 (LM1) seed from distributors (WH507, WH505 and Duma43), had high percentage of pure seeds while the seed from farmer saved and from local market had the lowest pure seed (Table 3.10). Farmer
saved seed and seeds from local markets had the highest percentage of inert matter and insect damaged seeds. In agro ecological zone 2 (LM2), maize variety WH507 from distributor had the highest percentage of pure seeds followed by variety WH 505 from distributor (Table 3.10). None of the seed sources met required regulation purity limit (99%) minimum recommended. In term of inert matter, variety IR/Kayongo followed by local market, farmer saved seeds and seeds from agro vet shops had percentage inert matter over the required regulatory limit of 0.95% maximum.

3.4.5 Seed germination and seedling vigor of maize seed samples

There were significant differences among the different seed sources from the two agro ecological zones in percentage germination, normal seedlings. Except variety IR/Kayongo, there were no significant differences among seeds from agro vet shops and seed companies/distributors (Table 3.11). Farmer saved and markets sourced seeds had significantly lower percentage germination and normal seedlings in both agro ecological zones (Table3 .11). Excluding variety IR/Kayongo, there was no significant variation in germination index, pure live seeds and vigor index among the seed from distributors. Farmer saved and local market seeds had lower pure live seeds and vigor index in both agro ecological zones (Table 3.11). However, all the seed varieties from the various sources met the recommended germination percentage threshold of 90% except variety IR/Kayongo.
Table 3.10: Percentage purity of maize seed from various sources in two agro ecological zones in Busia County during the long rain season 2017

<table>
<thead>
<tr>
<th>Seed sources/variety</th>
<th>Pure seeds</th>
<th>Other variety</th>
<th>Inert matter</th>
<th>Shriveled</th>
<th>Insect damage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Midland Zone I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distributor (WH 507)</td>
<td>96.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.8&lt;sub&gt;d&lt;/sub&gt;</td>
<td>2.9&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;d&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 505)</td>
<td>95.7&lt;sub&gt;a&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.9&lt;sub&gt;d&lt;/sub&gt;</td>
<td>3.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;d&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (Duma 43)</td>
<td>93.4&lt;sub&gt;a&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>1.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>5.2&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;d&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (IR/Kayongo)</td>
<td>76.6&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>3.4&lt;sub&gt;a&lt;/sub&gt;</td>
<td>19.5&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>0.5&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Agro vet (WH 507, WH 505, Duma 43, IR/Kayongo)</td>
<td>75.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>1.5&lt;sub&gt;c&lt;/sub&gt;</td>
<td>17.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.8&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Farmer saved (Sipindi,Panadol, Duma 43, IR/Kayongo)</td>
<td>69.9&lt;sub&gt;c&lt;/sub&gt;</td>
<td>11.8&lt;sub&gt;a&lt;/sub&gt;</td>
<td>1.5&lt;sub&gt;c&lt;/sub&gt;</td>
<td>16.2&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.6&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Local market (Sipindi and Panadol)</td>
<td>66.7&lt;sub&gt;d&lt;/sub&gt;</td>
<td>7.8&lt;sub&gt;b&lt;/sub&gt;</td>
<td>1.9&lt;sub&gt;b&lt;/sub&gt;</td>
<td>22.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>1.5&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>74.4</td>
<td>6.5</td>
<td>1.7</td>
<td>16.7</td>
<td>0.8</td>
</tr>
<tr>
<td>LSD (p≤0.05)</td>
<td>3.9</td>
<td>1.4</td>
<td>0.3</td>
<td>3.7</td>
<td>0.2</td>
</tr>
<tr>
<td>CV%</td>
<td>4.7</td>
<td>19.3</td>
<td>18.0</td>
<td>20.2</td>
<td>28.0</td>
</tr>
<tr>
<td><strong>Lower Midland Zone II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distributor (WH 507)</td>
<td>96.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.8&lt;sub&gt;e&lt;/sub&gt;</td>
<td>2.9&lt;sub&gt;f&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;d&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 505)</td>
<td>95.7&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.9&lt;sub&gt;e&lt;/sub&gt;</td>
<td>3.4&lt;sub&gt;ef&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;d&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (Duma 43)</td>
<td>93.4&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>1.4&lt;sub&gt;de&lt;/sub&gt;</td>
<td>5.2&lt;sub&gt;e&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;d&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (IR/Kayongo)</td>
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<td>0.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>3.4&lt;sub&gt;a&lt;/sub&gt;</td>
<td>19.5&lt;sub&gt;a&lt;/sub&gt;</td>
<td>0.5&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Agro vet (WH 507, WH 505, Duma 43, IR/Kayongo)</td>
<td>88.2&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>1.7&lt;sub&gt;d&lt;/sub&gt;</td>
<td>7.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>0.2&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Farmer saved (Sipindi,Panadol, Duma 43, IR/Kayongo)</td>
<td>72.2&lt;sub&gt;c&lt;/sub&gt;</td>
<td>10.9&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.2&lt;sub&gt;c&lt;/sub&gt;</td>
<td>14.1&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.7&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Local market (Sipindi and Panadol)</td>
<td>70.2&lt;sub&gt;f&lt;/sub&gt;</td>
<td>11.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.5&lt;sub&gt;b&lt;/sub&gt;</td>
<td>15.8&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.4&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>79.3</td>
<td>6.8</td>
<td>2</td>
<td>11.5</td>
<td>0.4</td>
</tr>
<tr>
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<td>0.8</td>
<td>0.5</td>
<td>1.6</td>
<td>0.2</td>
</tr>
<tr>
<td>CV%</td>
<td>2.1</td>
<td>10.2</td>
<td>21.6</td>
<td>12.2</td>
<td>39.9</td>
</tr>
</tbody>
</table>
**Table 3.11:** Germination and seedling vigour of maize seeds from various sources in two agro ecological zones in Busia County

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Germination</th>
<th>Normal seedlings</th>
<th>Germination Index</th>
<th>Pure Live seed</th>
<th>Vigor index 1</th>
<th>Vigor index 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Midland zone I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distributor (Duma 43)</td>
<td>98.5&lt;sub&gt;a&lt;/sub&gt;</td>
<td>82.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>35.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>92.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3,725.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3,986.0&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 505)</td>
<td>98.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>90.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>35.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>93.7&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3,518.0&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>3,730.0&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 507)</td>
<td>98.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>92.1&lt;sub&gt;a&lt;/sub&gt;</td>
<td>35.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>94.4&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3,147.0&lt;sub&gt;abc&lt;/sub&gt;</td>
<td>3,732.0&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Farmer saved (Sipindi, Panadol, Duma 43, IR/Kayongo)</td>
<td>95.0&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>75.4&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>33.8&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>66.4&lt;sub&gt;b&lt;/sub&gt;</td>
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<td>2,456.0&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Local market (Sipindi and Panadol)</td>
<td>92.6&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>75.4&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>32.7&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>66.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>2,606.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>2,158.0&lt;sub&gt;cd&lt;/sub&gt;</td>
</tr>
<tr>
<td>Agro vet (WH 507, WH 505, Duma 43, IR/Kayongo)</td>
<td>90.9&lt;sub&gt;cd&lt;/sub&gt;</td>
<td>69.8&lt;sub&gt;c&lt;/sub&gt;</td>
<td>32.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>67.3&lt;sub&gt;b&lt;/sub&gt;</td>
<td>2,847.0&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>3,065.0&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (IR/Kayongo)</td>
<td>86.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>14.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>29.8&lt;sub&gt;c&lt;/sub&gt;</td>
<td>66.1&lt;sub&gt;b&lt;/sub&gt;</td>
<td>676.0&lt;sub&gt;d&lt;/sub&gt;</td>
<td>1,732.0&lt;sub&gt;d&lt;/sub&gt;</td>
</tr>
<tr>
<td>Grand mean</td>
<td>93.3</td>
<td>71.9</td>
<td>33.1</td>
<td>70.2</td>
<td>2,706.9</td>
<td>2,693.2</td>
</tr>
<tr>
<td>LSD (p≤0.05)</td>
<td>5.4</td>
<td>10.6</td>
<td>2.2</td>
<td>14.0</td>
<td>823.6</td>
<td>567.1</td>
</tr>
<tr>
<td>CV%</td>
<td>5.1</td>
<td>13.6</td>
<td>6.1</td>
<td>18.5</td>
<td>28.1</td>
<td>19.5</td>
</tr>
<tr>
<td><strong>Lower Midland zone II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distributor (Duma 43)</td>
<td>98.5&lt;sub&gt;a&lt;/sub&gt;</td>
<td>82.7&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>35.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>92.0&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>3,725.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3,986.0&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 505)</td>
<td>98.0&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>90.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>35.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>93.7&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3,518.0&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>3,730.0&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 507)</td>
<td>98.0&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>92.1&lt;sub&gt;a&lt;/sub&gt;</td>
<td>35.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>94.4&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3,147.0&lt;sub&gt;abc&lt;/sub&gt;</td>
<td>3,732.0&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Farmer saved (Sipindi, Panadol, Duma 43, IR/Kayongo)</td>
<td>94.8&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>81.8&lt;sub&gt;c&lt;/sub&gt;</td>
<td>33.4&lt;sub&gt;b&lt;/sub&gt;</td>
<td>68.5&lt;sub&gt;c&lt;/sub&gt;</td>
<td>2,424.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>2,405.0&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Local market (Sipindi and Panadol)</td>
<td>94.9&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>81.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>33.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>70.9&lt;sub&gt;c&lt;/sub&gt;</td>
<td>2,429.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>2,153.0&lt;sub&gt;cd&lt;/sub&gt;</td>
</tr>
<tr>
<td>Agro vet (WH 507, WH 505, Duma 43, IR/Kayongo)</td>
<td>94.3&lt;sub&gt;c&lt;/sub&gt;</td>
<td>87.2&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>33.6&lt;sub&gt;b&lt;/sub&gt;</td>
<td>80.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>2,816.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>3,160.0&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (IR/Kayongo)</td>
<td>86.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>14.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>29.8&lt;sub&gt;c&lt;/sub&gt;</td>
<td>66.1&lt;sub&gt;c&lt;/sub&gt;</td>
<td>676.0&lt;sub&gt;d&lt;/sub&gt;</td>
<td>1,732.0&lt;sub&gt;d&lt;/sub&gt;</td>
</tr>
<tr>
<td>Grand mean</td>
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<td>81.0</td>
<td>33.6</td>
<td>75.6</td>
<td>2,594.4</td>
<td>2,704.0</td>
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<tr>
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<td>6.9</td>
<td>1.3</td>
<td>13.1</td>
<td>781.7</td>
<td>565.6</td>
</tr>
<tr>
<td>CV%</td>
<td>3.3</td>
<td>7.9</td>
<td>3.6</td>
<td>16.0</td>
<td>27.9</td>
<td>19.4</td>
</tr>
</tbody>
</table>
3.4.6 Infections of maize seed with disease causing pathogens

There were no significant differences in intensity of infected seeds among the seeds from agrovet shops and seed distributors except variety IR/Kayongo (Figure 3.9). Farmer saved and local market seeds had high incidence of infected seedlings, *Fusarium sp*, *Aspergillus sp* and *penicillium sp* diseases causing pathogens in both agro ecological zones (Table 3.12).

![Figure 3.9: Percentage of infected maize seed from different seed sources in two agro ecological zones in Busia County](image)

Figure 3.9: Percentage of infected maize seed from different seed sources in two agro ecological zones in Busia County
Table 3.12: Percentage of Fungal genera isolated from maize seed sources in two Agro Ecological Zones in Busia

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Infected seedlings</th>
<th><em>Fusarium</em> sp</th>
<th><em>Aspergillus</em> sp</th>
<th><em>Penicillium</em> sp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Midland Zone I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local market (Sipindi and Panadol)</td>
<td>37.9&lt;sub&gt;a&lt;/sub&gt;</td>
<td>32.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>16.6&lt;sub&gt;b&lt;/sub&gt;</td>
<td>12.4&lt;sub&gt;bc&lt;/sub&gt;</td>
</tr>
<tr>
<td>Farmer saved (Sipindi, Panadol, Duma 43, IR/Kayongo)</td>
<td>30.9&lt;sub&gt;b&lt;/sub&gt;</td>
<td>29.9&lt;sub&gt;a&lt;/sub&gt;</td>
<td>15.3&lt;sub&gt;b&lt;/sub&gt;</td>
<td>39.2&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (IR/Kayongo)</td>
<td>11.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>27.5&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>35.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>27.5&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 505)</td>
<td>1.0&lt;sub&gt;d&lt;/sub&gt;</td>
<td>17.5&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 507)</td>
<td>0.8&lt;sub&gt;d&lt;/sub&gt;</td>
<td>15.0&lt;sub&gt;cd&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Agro vet (WH 507, WH 505, Duma 43, IR/Kayongo)</td>
<td>6.2&lt;sub&gt;cd&lt;/sub&gt;</td>
<td>8.8&lt;sub&gt;cd&lt;/sub&gt;</td>
<td>30.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>4.4&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (Duma 43)</td>
<td>1.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>6.8&lt;sub&gt;d&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Grand mean</td>
<td>21.1</td>
<td>19.6</td>
<td>13.8</td>
<td>11.9</td>
</tr>
<tr>
<td>LSD (p=0.05)</td>
<td>6.03</td>
<td>10.4</td>
<td>8.2</td>
<td>15.2</td>
</tr>
<tr>
<td>CV%</td>
<td>26.5</td>
<td>35.8</td>
<td>40.1</td>
<td>85.9</td>
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<tr>
<td><strong>Low Midland Zone II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local market (Sipindi and Panadol)</td>
<td>30.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>36.8&lt;sub&gt;a&lt;/sub&gt;</td>
<td>35.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>33.3&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Farmer saved (Sipindi, Panadol, Duma 43, IR/Kayongo)</td>
<td>27.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>23.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>35.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>35.0&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (IR/Kayongo)</td>
<td>11.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>20.0&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>31.1&lt;sub&gt;a&lt;/sub&gt;</td>
<td>10.0&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 505)</td>
<td>1.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>15.0&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>10.0&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (WH 507)</td>
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<td>12.5&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>12.5&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Agro vet (WH 507, WH 505, Duma 43, IR/Kayongo)</td>
<td>4.2&lt;sub&gt;c&lt;/sub&gt;</td>
<td>11.3&lt;sub&gt;c&lt;/sub&gt;</td>
<td>12.5&lt;sub&gt;b&lt;/sub&gt;</td>
<td>5.6&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Distributor (Duma 43)</td>
<td>1.3&lt;sub&gt;c&lt;/sub&gt;</td>
<td>12.5&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>5.0&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Grand mean</td>
<td>17.5</td>
<td>18.8</td>
<td>16.3</td>
<td>15.9</td>
</tr>
<tr>
<td>LSD (p=0.05)</td>
<td>6.2</td>
<td>10.1</td>
<td>8.8</td>
<td>9.7</td>
</tr>
<tr>
<td>CV%</td>
<td>32.6</td>
<td>36.1</td>
<td>36.4</td>
<td>41.2</td>
</tr>
</tbody>
</table>
3.5 Discussion

3.5.1 Maize production practices in Busia County

The majority of the maize producers in Busia County are small-scale farmers whose maize production farm varies between 0.5-1.5 ha. Most of the seed used by farmers are from traditional or informal system though the majority is aware of the certified maize seeds. Similar findings have been reported from various studies which show that majority of farmers in Africa are small scale with small land holdings of less than two Ha but contribute to over 70% of maize production (Oladeeb, 2004; Mbithi, 2000; Dan-Azumi, 2001; Jayne et al., 2014; Boone, 2015).

Farm size may be influenced by the number of the population. Also, in western Kenya, agriculture business is low resulting in deprived farmhouse management though the availability of high man-land proportions. This is in agreement with the study by Kanyinga (2009) and Jenkins (2012) who found that land availability is influenced by population density. Usually, the land is divided into small portions for descendant. Stephen (2013) observed that farm size does not constitute problem in African agriculture compared to the other smallholder farmers in Japan, China, and other developed countries. In Asia, it had been proved that the size of farm doesn’t constitute the key factor for productivity. Nieuwoudt (1990) proved that small-scale maize producers can utilize their farm greater than large scale farmers. This view was also supported by Latt and Nieuwoudt (1988), in categorized analysis of input use study, they reported that land of less than one hectare used intensive inputs than big farms, large than one hectare. Therefore signifying that small-scale farmers may maximize the output of the possessed plot, and large-scale maximizes returns to labor and capital (Baumgartne et al., 2015).

Majority of small-scale farmer still practice traditional agriculture by using landraces. Studies by Opole (2003), Grain (2007), Wekundal (2012), Biemond et al. (2013) and Dogbe et al. (2014)
also reported that a large number of African states rely on seed recycling. In contrast to the finding of Mcguire and Sperling (2016), they indicated that local market constitutes the main source of the seed in SSA. Nevertheless, both farmers saved and local market seeds are among informal seed sources. The reason is that Farmer saved and local market seeds or seeds from informal sector are easier to access at the right time, free exchangeable or low cost (Coomes et al., 2015). As recognized by McGuire and Sperling (2016), and USAID (2015), farmer saved seed remains common although the seed industry is well organized in East and Central Africa. The Africa Centre for Biodiversity (2015) also find that in Sub Saharan Africa, the planting material used by small-scale producers are from own stock from previous seasons harvest, showing also that seed system in ECA is multi-structured, classified being formal, semi-formal and informal. Also, CTA (2014), revealed that excellent enhancement in traditional seed sector and improved relations to the public seed sector are critical.

As the study showed, the seed industry is composite and active in Busia County by consideration of the different sources including certified and uncertified/Own saved/local market maize seed used. Similar study done by MacRobert (2013) showed that the seed industry is composed of farmers’ system where farmers use their own saved seed from their harvest and the regulated system where the government and private sector influence the seed multiplication and trading.

Farm saved seed is available to the farmer at any time of sowing and easy to access at low cost. Coomes et al. (2015) observed that farmers seed delivery system alleviate transaction and conveyance costs and distance which make the seed accessible to growers at right time (Dube et al., 2014). The found of Nyoro (2002) stated that farmers in Western and Central Kenya utilize local varieties and recycle hybrids due to lack of confidence in new certified maize seeds from many seed companies in the region. According to Feder (1985) from similar study, lack of credit
is one of the factors limiting farmers adopting new improved maize varieties. Sperling (2001) also reported that the seed from informal system are easier to access with low cost. Adidjah (2011) concluded that farmers hesitate on the true maize material to utilize due to numerous maize seed varieties from different companies in the region.

Khan and Keateng (2000) in their survey carried out on awareness of agriculture producers and their level of adoption of the recommended storage methods; show that because of issues of revenue availability, majority of farmers store their stock in their traditional manner than the recommended improved methods of storage (Fisseha et al., 2014). To prevent their seeds from pests, farmers apply ash or actelic, others do not apply any treatment (Wambugu et al., 2009).

Wangari (2017) from his report on the adoption of seed varieties specified that permanent food insecurity in Kenya is attributed to poor harvest from agriculture (Sasson, 2012). KEHIS has certified more than 250 maize cultivars, although farmers accepted these hybrids varieties, they don’t agree that the expected output is not realized because of low input and inadequate agronomic practices. Farmers dissatisfied by poor germination or by seed-borne disease lose confidence in the seed producer (Tripp, 2001). Farmers do not apply fertilizer sufficiently to the recommended rate among additional inputs.

From this study, farmers indicated several pests affecting their maize crop. Armyworms were reported to be the most devastating the field on maize in Busia. Also, Midega et al (2017) reported that Armyworms invaded Africa, instigating considerable destruction to maize and other crops. The pest entered Africa, with the principal discoveries being stated in Central and Western Africa in early 2016 (Goergen et al., 2016). The other major constraint, threatening the maize crop is *Striga hermonica* that affects much the crop ending in low yield when the weed is not
managed on time. Other pests cited were cutworms, Termites and Stalk borers. Similar study done by Woomer et al. (2015), also found that Striga is a dangerous weed living depending on maize crop, reduce greatly yield and causes the plant not respond to expected management. Andika et al. (2011) cited factors affecting food security in Busia. These included incidence of Striga, diseases, lack of adequate technical knowledge, and high cost of inputs, seed acquirement and land preparation (De Groote et al., 2010; Hearne, 2009). Farmers practice weeding and apply soap diluted in water, and ash to manage the pests. Innocent (2017) reported that pests are the major challenges among others, affecting agricultural production in Busia County and thus affect products availability in the market. Few farmers spray chemical/pesticide. Ahmed et al. (2017) reported that farmers do not have access to credit for covering necessary agriculture inputs including seeds, fertilizers, chemical or pesticides and fungicide to protect their crops.

Small-scale maize producers in Busia County cultivate maize for subsistence. Farmers declared soil infertility recognized in plant as deficiency and ear rot as challenges to maize productivity. Head smut, maize streak virus (MSV) and maize lethal necrosis (MLN) were also reported. To reduce the incidence of diseases, 78.3% of farmers did not have information on the threat management. Others, 7.5%, prefer CAN as top dressing to allow the crop to recover for the deficiency while others uproot the plant with symptoms. Thus, the average maize production gained by farmers in the County is between 200 – 600 kg per acre. Similar results were found by Woomer and Mulei (2015) who reported that maize yield in West Kenyan regions are most of the time 500kg per acre. Badu (2014), Meng and Ekboir (2000) also observed that maize has major problems limiting developing countries from attaining self-sufficiently in production which is estimated at 500kg per ha compared to developed counties.
3.5.2 Quality of farmers’ maize seed in Busia County

Certified seeds from Distributors and Agro vet shops had high percentage of pure seeds than uncertified seeds but all the maize seed sources did not meet the recommended maize seed purity of the Kenyan laboratory standard (99%). Current result is consistent to finding of Ochichi (2015) and Kariuki (2014) who observed variations in pure seed content of farmer seed in Western Kenya. Seeds from the formal sector are not adulterated, they are pure comparing to the seed from own saved. Previous studies done by Coomes et al. (2015) found that seeds from the formal sector are not adulterated, they are free from weed seeds or inert material comparing to the seed from own saved. Sperling (2001) and Mahender et al. (2015) also indicated that seed quality refers to it trueness to it varietal type and physical attribute (Oshone et al., 2014).

All the seed sources met the recommended germination percentage, 99%, except distributor IR/Kayongo which had germination rate of 86.3% and low percentage of normal seedlings. Farmer saved and market maize seeds were highly contaminated and had low vigor index. Fungal seed borne was isolated from all sources though informal seeds were found to have more different fungal genera. This is in agreement with the found of Amaza et al. (2010) concretizing that seed recycling leads to poor seed quality, influencing production (Amodu et al., 2015). Louwaars (2007) also indicated that seed quality consists of it genetic purity, physical purity, germination potential, vigor and free from seed borne pathogens (Amodu et al., 2015). Various studies found that farmer saved seed does not meet the finest quality (Dornbos, 1995; Powell et al., 1984). Maddox (1998) concluded that seed borne pathogens reduce germination potential. Seed from informal sector are of west quality, inappropriate varieties, infected seed of low germination potential with compromised yield (IRRI, 2013).
This aspect could be attributed to the reason that farmer seeds are produced in ordinary agriculture production system with no regulation regarding harvest and handling, drying and storage (Ochichi 2015). Delouche (1982) also found that about 80% of the amount of the maize seeds used by farmers in western Kenyan counties are from own farm production as observed Louwaar (1994) that this kind of seed production seems to ignore certain aspects of seed quality. Though informal seeds constitute about 60-80% of the total planting material used in East and Central Africa, they are of underestimated quality (CTA, 2014).

Farmer saved and local market seeds were highly infected with high number of fungal pathogens. This is in agreement with the find of IRRI (2013) who indicated that informal seeds are of poor quality, infected seed with compromised yield. CTA (2014) also found that though seeds from informal system constitute the main source of planting material used in East and Central Africa, they are of underestimated quality (Amaza et al. 2010; Louwaars, 2007; Dornbos, 1995 and Powell et al., 1984). Biemond et al. (2013) reported that farmer saved cowpea seeds were highly infected with multiple seed-borne disease causing pathogens. Dauda et al (2017) also indicated that own saved seeds of onion had high infection of fungal pathogens.

Farmers’ seeds are most of time produced in the combined standards of crop production system. Seeds are selected from seasonal production after harvest or earlier planting. Farmers’ methods of seeds production and handling are at the same time the rudimentary. These seeds are out of control or not certified and tested by the seed certification agency, thus, result in poor quality which may be induced by poor farm management, Storage system and period, store conditions that favor growth of different seed borenes fungi. This statement is in agreement with Basra (1995) and Powell et al., (1985) who indicated that farmer saved seeds are produced under uncontrolled system, as consequence, they result in poor quality with fungal seed borne and
mycotoxin. Adetumbi and Olakoje (2010) observed that seed storage is crucial for seed quality. It can have impact on the whole feature of seeds quality attributes and contributes to seed ageing that decreases seed viability. Also, Bennett & Klich (2003) observed that storage is necessary for seed fitness maintenance. Store environments must remain properly cleaned to prevent leftover contagions from diseased vegetable or seed material saved from the previous harvest. In relation to seed testing, storage is important when the testing and planting dates are far apart (Mizza, 2015; Jordan et al., 1986; Abdullah et al., 2011; Valquiria et al., 2013; Adetumbi and Olakoje, 2010).

Maize producers are small-scale farmers who appeal to farmyard manure to fertilize their maize crops. Farmers relied on their farm-saved seeds which do not meet the minimum requirement of the seed quality standard. Various study reported also that farmers in most of the African countries are small scale who do not apply effort to acquire improved seeds and do not adopt new agriculture technology or the few adopters do not apply it adequately.
CHAPTER FOUR
EFFECT OF FARM SAVED MAIZE (*Zea mays* L.) SEEDS ON INTENSITY OF FOLIAGE DISEASES

4.1 Abstract

Access to high quality certified seed by farmers resulting in the recycling of own farm-saved seeds that are contaminated with diseases, low vigor and result in low yields. The study was conducted to determine the effect of recycling of maize seeds on the incidence of and severity of diseases. Maize seed collected from farmers, local market and Agrovet shops in Busia County were subjected to field evaluation at Madola in Busia County and Kenya Agriculture and Livestock Research Organization (KALRO) field station in Kakamega County. The seeds were planted during 2017 long rain season and data collected included emergence, plant height, off types, ear aspect and abnormalities, incidence and severity of diseases and yield.

Seeds from the local market had significantly the highest emergence at 65.7% while seeds from farmers and local markets had the highest percentage off-type of up to 18%. Farmer saved and seeds from local market resulted in plants that were highly susceptible to stalk lodging and ear abnormalities. They also showed high incidence and severity of diseases including northern leaf blight, gray leaf spot, diplodia, rust, Brown spot, downyy mildew, eyespot and ear rot. Seeds from agro vet shops had significantly lower incidence and severity of fungal diseases and highest yield depending on the variety. The study showed that though informal seeds had high plant establishment, they had high level of off-types, are susceptible to lodging, diseases and low yields. Therefore, farmers should be encouraged to use certified or improved seeds to enhance crop productivity.

**Keywords:** Maize, maize diseases, seed quality, seed sources, yield
4.2 Introduction

Maize is the main cereal food crop in Africa (Westengen et al., 2014) but yield remains low, below 2,000kg ha\(^{-1}\) while in other countries such as United State produces an average yield of 7,000 to 10,000 kg ha\(^{-1}\) (Huang et al., 2011). Crop productivity remains low due to several reasons including poor adoption of improved agriculture technology and the majority of food producers are small-scale farmers who depend on their own farm-saved seeds constituting around 80 – 90% of the planting material used (Bruijin et al., 1994, Wright et al., 1994, Delouche, 1982).

Farmer saved seeds are inappropriate varieties which can carry noxious weed seeds and seed-borne diseases leading to poor emergence in the field and low yield (Sperling, 2001). Seed from the informal system consists of low quality, inappropriate varieties, infected seed of low germination potential with compromised yield (Sperling, 2001, Mahender et al., 2015). Seed quality is the base and the most critical factor determining development of the crop, thus high yield. Louwars et al. (1997) reported that good quality seed is the crucial input for plant productivity and unique way to maximize on other agricultural inputs.

Maize seed quality refers to it trueness to it varietal type, physical attribute, ability to germinate, vigor and it should be free from seed borne diseases. Poor quality seeds result in defective seedling stand and more infected crops in the field (Coutts et al., 2008; IRRI, 2013). Frequent use of seed of unknown quality by smallholder farmers will end in decline in maize productivity. Farmer saved seed may constitute a source of dangerous pathogens and may carry unwanted plants which by time could spread and aggravate the problem in the environment (Zegeye et al., 2014). In contrast to the certified seeds, the seeds from the formal system may resistant to pests, diseases and abiotic stress depending on the objective they have been developed for and thus
perform with high yield (Zegeye et al., 2014, Alemu, 2015). They are certified for their acceptability in performance and their related productivity in term of yield and grain quality.

Improving seed attributes improves the possible output of the material significantly (Atilaw, 2010). Use of high quality and clean seeds is likely to increase yields by 5-20% (Asea et al., 2010; Mew and Gonzales 2002). Seeds of improved attributes are of potentiality to increase the agricultural production up to 25-50% (CTA, 2014; Gebremedhim, 2015). The maize varieties that farmers are using are landraces developed since 1988 (IFPRI, 2012). Informal seeds raise a fundamental subject on the quality attributed that could affect farmers’ expectation. This study focuses on the assessment of the performance of maize seeds from different sources including farmer saved, local market and the certified seeds from the agro-dealers.

4.3 Materials and methods

4.3.1 Experimental design and layout

The study was conducted during 2017 long rain season in farmer field at Busia County which is described in 3.1.1., and Kakamega County at KALRO field station located at 1554m Altitude, Latitude 00°17’N and Longitude 34°47’E., the mean rainfall is between 1600 and 2000mm, the soil is a Nitosol well-drained, deep dark red friable (Jaetzold, and Schmidt, 1983).

Land preparation, both digging and harrowing, was done manually. Treatments of the experiment included landraces Sipindi and Panadol from farm-saved and local market, Duma 43 and IR/Kayongo from farm-saved and seed from agro vet shops including Duma 43 and IR/Kayongo laid in a randomized complete block design with three replicates. Blocks were separated by 1 m and plots of 3m x 4m within blocks were separated by 0.75m. Two seeds per hill were planted in each row having 11 hills separated by 30cm in each plot having 5 rows
distanced by 75cm. Two guard rows were installed around experiment in both sites to protect crops within blocks from external negative effects such as animal chewing crops, thieves. As described by Muiru et al (2015) fertilization was applied at the rate of 10g of DAP per hill at the planting and CAN top dressing at a rate of 10g per hill applied at the 45cm knee-high level of the crop as described by Qasim et al (2010) and Halidu et al (2014). Data were recorded on emergence, incidence of seedling blight, viral diseases, off types, plant stand, diseases incidence and severity scoring of fungal diseases, number of cobs per plant, cobs aspect and weight, yield and yield component.

4.3.2 Assessment of agronomic parameters

The agronomic parameters recorded included emergence, dead seed, rotten seeds, off-types, root and stalk lodging and ear aspects. The emergence was determined after 50% seedlings had two fully expanded leaves as described by Kieran (2009), Ogunniyan and Olakojo (2015). Dead seeds were assessed by checking hills where the seed did not emerge whether it was absent or rotten. Off-types crops were assessed in each plot as described by Hipi et al. (2013), by observing the morphological characteristics of the crop including Leaves shapes, tassel coloration at the base glume, silks color, plant length, ear and kernel coloration (UPOV, 2009; Yadav and Singh, 2010) based on their descriptors. Root and stalk lodging were recorded every month and at harvest as a percentage of the lodged plant over the total number of plants in each plot. Ear aspect (EASP) was scored by observing husks, morphology of the ear, at a scale rate of 1-5, where 1 is clean, uniform, large, and well-filled and 5 is rotten, variable, small, and partially filled ears (Moses and Abebe, 2015).
4.3.3 Assessment of incidence and severity of foliage diseases

Diseases assessed were maize streak virus, maize lethal necrosis, northern leaf blight, gray leaf spot, rust, diplodia, eyespot down mildew and ear rot. Incidence of viral diseases was determined on all plants in the 3 intermediate rows in each plot as described by Bosque-Perez et al. (1998). Disease incidence was based on visual symptoms while assessment of the major maize viral diseases including maize streak virus and maize lethal necrosis, was carried out three times at vegetative stage during the season.

Inspection was done as described by CIMMYT (2004) at vegetative stage growth at V5, V10, VT before pollen development and R2 (Appendix 4) and at harvest. At each stage, plant stand was computed while Incidence was determined as the percentage of the plants infected over the total number of plants in each plot. Severity was scored on 6 plants showing symptoms selected randomly on proportion of 2 per row on the three intermediate rows in each plot at 0-5 scale as described by Nwanosike et al. (2015) and Reid et al (1996) as 0= no symptoms, 1= very slight infections, one or two restricted lesion on lower leaves or 1-9 trace. 2= slight infections, 9-15 lesions on lower leaves. 3= moderate number of lesions on lower leaves. 4= abundant lesions on lower and middle leaves which extend to upper leaves, and 5= abundant infections, no formation of cobs, plant dying prematurely from the disease. Severity of ear rot was scored using rating scale of 1-7 as 1=no infection, 2= 1 to 3% infection, 3= 4 to 10%, 4= 11 to 25%, 5= 26 to 50%, 6= 51 to 75 % and 7= over 75% of infected ear (Shekhar and Kumar, 2012).

4.3.4 Assessment of yield and yield components

Ears from the rows within each plot were counted, harvested at physiological maturity, weighed for yield determination. Number of ears per plant and ear abnormalities including incomplete kernel tip set, poor tip fill, bouquet ears, exposed ear tip, extended ear leaves, tassel ears and
zipper ears, were recorded as a percentage of ear presenting abnormalities over the total number of ears in each plot. Grain yield was determined in kg ha⁻¹ based on the weight of unshelled cobs at physiological maturity, considering the commercial grain moisture of 12.5% and shelling factor of 80% using the formula below as described by Adebayo and Menkir (2015).

\[
GY \left( \frac{Kg}{ha} \right) = WW \times \frac{100 - FM}{100 - 12.5} \times \frac{80}{100} \times \frac{10,000}{US}
\]

Where GY is Grain yield, WW the wet weight, FM the field moisture and US the Useful surface.

4.3.5 Data analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT 15th edition. Mean separation was done using Fischer’s protected Least Significant Difference (LSD) at 5% level of significance.

4.4 Results

4.4.1 Agronomic parameters

There was significant variation (p ≤ 0.05) in 50% emergence of the different seed sources between the sites. The result showed higher emergence percentage at Busia compared to Kakamega. Emergence percentage varied significantly among the seed sources at p ≤ 0.05 (Table 4.1). Uncertified seeds from farmer-saved and local market had about 43% emergence over the certified from agro vet shops. Panadol from local market had the highest emergence rate of about 63% while the certified IR/Kayongo from agro vet had the lowest in both sites. Dead seeds showed significant statistical variation in Busia. Certified seeds from agro vet shops showed high incidence of dead seeds of about 26% over uncertified seeds from farmer-saved and local market seeds. However, IR/Kayongo from agro-vet shop had the highest percentage of dead seeds of
about 33% across the sites. Rotten seeds varied between the sites. There was no significant difference at Busia while at Kakamega, the result showed significant variations in percentage of rotten seeds among the seed sources (Table 4.1). Certified seeds from agro vet shops had the highest percentage of rotten seeds of about 20% compared to uncertified seeds from farmer-saved and local market seeds. However, IR/Kayongo from agro-vet shop had the highest percentage of rotten seeds in both sites (Table 4.1).

The result showed significant variation at p≤0.05 in off-types among the seeds from the various sources in both sites. Uncertified seeds from farmer saved and local market had high number of off-types of about 9% in contrast to certified seeds from agro vet shops having about 5% at Busia site while at Kakamega, the informal seeds had about 17% of off-type and formal seeds from agro vet shops had about 3%. However, Sipindi from farmer-saved had high number of off-types crops across the sites (Table 4.2). Stalk lodging did not show significant variation between the sites. At both sites, uncertified seeds from farmer saved and local market had high incidence of stalk lodging at 49.4% over certified seeds from agro vet shops (table 4.2).

Table 4.1: Percentage emergence, dead and rotten seeds of different seed sources in Busia and Kakamega sites

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Busia</th>
<th></th>
<th></th>
<th>Kakamega</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emergence</td>
<td>Dead seeds</td>
<td>Rotten seeds</td>
<td>Emergence</td>
<td>Dead seeds</td>
<td>Rotten seeds</td>
</tr>
<tr>
<td>Panadol local Market</td>
<td>65.8&lt;sub&gt;a&lt;/sub&gt;</td>
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<td>12.1</td>
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<td>16.4</td>
<td>11.5&lt;sub&gt;b&lt;/sub&gt;</td>
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<tr>
<td>Sipindi farmer saved</td>
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<td>16.7&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>14.2</td>
<td>53.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>23.3</td>
<td>12.4&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>IR/Kayongo farmer saved</td>
<td>55.8&lt;sub&gt;b&lt;/sub&gt;</td>
<td>18.2&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>16.1</td>
<td>39.4&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>23.3</td>
<td>18.2&lt;sub&gt;b&lt;/sub&gt;</td>
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<tr>
<td>Sipindi local market</td>
<td>52.4&lt;sub&gt;b&lt;/sub&gt;</td>
<td>18.8&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>14.2</td>
<td>53.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>21.5</td>
<td>15.2&lt;sub&gt;b&lt;/sub&gt;</td>
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<tr>
<td>Duma 43 farmer saved</td>
<td>52.4&lt;sub&gt;b&lt;/sub&gt;</td>
<td>20.3&lt;sub&gt;b&lt;/sub&gt;</td>
<td>15.5</td>
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<td>17.9</td>
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<td>19.4&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>17.6</td>
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<td>23.3</td>
<td>19.1&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
<tr>
<td>Duma 43 Agro vet</td>
<td>49.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>15.2&lt;sub&gt;c&lt;/sub&gt;</td>
<td>12.4</td>
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<td>14.2&lt;sub&gt;b&lt;/sub&gt;</td>
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<tr>
<td>IR/Kayongo Agro vet</td>
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<td>30.6&lt;sub&gt;a&lt;/sub&gt;</td>
<td>25.8</td>
<td>24.2&lt;sub&gt;c&lt;/sub&gt;</td>
<td>35.5</td>
<td>26.4&lt;sub&gt;a&lt;/sub&gt;</td>
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<tr>
<td>Grand Mean</td>
<td>55.9</td>
<td>19.4</td>
<td>16.0</td>
<td>47.0</td>
<td>21.9</td>
<td>16.9</td>
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<tr>
<td>LSD (p≤0.05)</td>
<td>21.5</td>
<td>5.1</td>
<td>9.8</td>
<td>20.4</td>
<td>23.5</td>
<td>7.7</td>
</tr>
<tr>
<td>CV%</td>
<td>21.9</td>
<td>15.0</td>
<td>35.1</td>
<td>24.7</td>
<td>61.2</td>
<td>25.8</td>
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</table>
Table 4.2: Percentage off-types and plant lodging of the seed from various sources at Busia and Kakamega sites

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Busia</th>
<th></th>
<th></th>
<th>Kakamega</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Off-types</td>
<td>Root lodging</td>
<td>Stalk lodging</td>
<td>Off-types</td>
<td>Root lodging</td>
<td>Stalk lodging</td>
</tr>
<tr>
<td>Panadol farmer saved</td>
<td>10.6&lt;sub&gt;a&lt;/sub&gt;</td>
<td>7.7</td>
<td>11.5&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>14.6&lt;sub&gt;a&lt;/sub&gt;</td>
<td>5.3</td>
<td>12.2&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Duma 43 farmer saved</td>
<td>10.4&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>7.5</td>
<td>10.4&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>15.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>6.1</td>
<td>12.9&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Sipindi local market</td>
<td>9.2&lt;sub&gt;abc&lt;/sub&gt;</td>
<td>6.4</td>
<td>14.1&lt;sub&gt;a&lt;/sub&gt;</td>
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<td>5.8</td>
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<td>7.1</td>
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<td>6.0</td>
<td>11.0&lt;sub&gt;a&lt;/sub&gt;</td>
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<tr>
<td>IR/Kayongo Agro vet</td>
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<td>7.6</td>
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<td>Panadol local Market</td>
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<td>3.1&lt;sub&gt;d&lt;/sub&gt;</td>
<td>7.9</td>
<td>3.7&lt;sub&gt;c&lt;/sub&gt;</td>
<td>2.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>5.8</td>
<td>2.8&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Grand mean</td>
<td>7.7</td>
<td>7.3</td>
<td>10.3</td>
<td>13.4</td>
<td>5.8</td>
<td>10.8</td>
</tr>
<tr>
<td>LSD (p≤0.05)</td>
<td>3.4</td>
<td>2.7</td>
<td>5.3</td>
<td>10.3</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>CV %</td>
<td>24.8</td>
<td>21.5</td>
<td>29.4</td>
<td>43.9</td>
<td>19.7</td>
<td>13.3</td>
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</table>

4.4.2 Incidence and severity of diseases

Major diseases observed included Seedling blight, maize streak, northern leaf blight, grey leaf spot, rust, diplodia, downy mildew, brown spot, eyespot and ear rot. Seedling blight, Northern leaf blight, and downy mildew were the commonest folia diseases affecting the maize from various sources in both Busia and Kakamega sites. Except at Busia, where maize streak virus, rust, brown spot which hab significant differences compared to Kakamega where high incidences were observed in northern leaf blight, diplodia, grey leaf spot and downy mildew. There were no much variations in the incidence of seedling blight between the sites at p≤0.05. At both sites, certified seeds from agro vet shops had the highest incidence of seedling blight and maize streak virus. However, IR/Kayongo from agro vet shops was highly contaminated with seedling blight and maize streak virus at both sites (Table 4.3).
The result showed at both sites, highly significant variations of fungal foliage diseases incidence between the seed sources. At Busia site, uncertified seeds from farmer saved and local market were found to be more infected having high incidence of diseases including northern leaf blight (17%), diplodia (6%) rust (4%), brown spot (3%) while certified seeds from agro vet shops had high incidence of downy mildew only. At Kakamega, the result revealed a reverse situation whereby the certified seeds from agro vet shops had a high level of diseases incidence of about 20% for northern leaf blight, grey leaf spot at 6% incidence, diplodia 12% and down mildew 6% (Table 4.4). Across the sites, the result showed that certified seeds from agro vet shops had high incidence of northern leaf blight (17%), grey leaf spot (3%), downy mildew (3%) while incidence of rust (4%), brown spot (4%) and eye spot (3%) were highly found in uncertified seeds from farmer saved and local market (Table 4.4).

Severity score of fungal diseases was significantly different between the sites and among the seed sources. At Busia site, diplodia was significantly different among the seeds sources whereas, at Kakamega, variations were found in northern leaf blight, grey leaf spot, diplodia and eyespot. Diplodia was found to be severe in uncertified seeds at Busia site while at Kakamega site, high severity scores of northern leaf blight, grey leaf spot were found in certified seeds from agro vet shops (Table 4.5).

Incidence and severity scores of ear rot were found to be highly significant among the seeds sources at Busia site, whereas at Kakamega there was non-significant difference. Farmer saved and local market seeds had high incidence of 10.5% and severity score of up to 6 indicating 51 to 75% infection on ears compared to certified seeds from agro vet shops (Table 4.6). However, local market, although had high plant establishment as indicated in table 4.1, had high incidence and severity of ear rot (Table 4.6).
### Table 4.3: Incidence of seedling blight and maize streak virus of the seed sources at Busia and Kakamega sites

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Incidence</th>
<th>Severity scores</th>
<th>Incidence</th>
<th>Severity scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Busia</td>
<td>Maize</td>
<td>Kakamega</td>
<td>Maize</td>
</tr>
<tr>
<td></td>
<td>Seedling blight</td>
<td>Maize streak</td>
<td>Seedling blight</td>
<td>Maize streak</td>
</tr>
<tr>
<td>IR/Kayongo Agro vet</td>
<td>39.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>13.4&lt;sub&gt;a&lt;/sub&gt;</td>
<td>46.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>11.4</td>
</tr>
<tr>
<td>Sipindi local market</td>
<td>27.9&lt;sub&gt;b&lt;/sub&gt;</td>
<td>8.5&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>31.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.0</td>
</tr>
<tr>
<td>Panadol local Market</td>
<td>21.4&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>7.8&lt;sub&gt;bc&lt;/sub&gt;d</td>
<td>21.9&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>0.0</td>
</tr>
<tr>
<td>Panadol farmer saved</td>
<td>20.6&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>10.6&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>29.1&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>0.0</td>
</tr>
<tr>
<td>Duma 43 farmer saved</td>
<td>20.3&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>9.8&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>24.2&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>2.4</td>
</tr>
<tr>
<td>IR/Kayongo farmer saved</td>
<td>18.7&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>4.8&lt;sub&gt;cd&lt;/sub&gt;</td>
<td>29.5&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>5.3</td>
</tr>
<tr>
<td>Sipindi farmer saved</td>
<td>18.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>8.2&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>20.7&lt;sub&gt;c&lt;/sub&gt;</td>
<td>5.3</td>
</tr>
<tr>
<td>Duma 43 Agro vet</td>
<td>7.9&lt;sub&gt;d&lt;/sub&gt;</td>
<td>3.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>6.5&lt;sub&gt;d&lt;/sub&gt;</td>
<td>0.0</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>21.8</td>
<td>8.0</td>
<td>26.2</td>
<td>31.4</td>
</tr>
<tr>
<td>LSD (p=0.05)</td>
<td>9.4</td>
<td>4.9</td>
<td>10.1</td>
<td>10.4</td>
</tr>
<tr>
<td>CV%</td>
<td>24.7</td>
<td>33.4</td>
<td>22.0</td>
<td>18.8</td>
</tr>
</tbody>
</table>

### Table 4.4: Incidence and severity score of ear rot of the different seed sources in Busia and Kakamega sites

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Incidence</th>
<th>Severity scores</th>
<th>Incidence</th>
<th>Severity scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Busia</td>
<td></td>
<td>Kakamega</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panadol local Market</td>
<td>14.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>5.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>44.4</td>
<td>7.0</td>
</tr>
<tr>
<td>Sipindi local market</td>
<td>11.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>6.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>49.6</td>
<td>7.0</td>
</tr>
<tr>
<td>Duma 43 farmer saved</td>
<td>10.2&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>4.3&lt;sub&gt;b&lt;/sub&gt;</td>
<td>55.5</td>
<td>7.0</td>
</tr>
<tr>
<td>Panadol farmer saved</td>
<td>9.4&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>5.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>54.3</td>
<td>6.0</td>
</tr>
<tr>
<td>IR Agro vet</td>
<td>9.3&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>3.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>53.9</td>
<td>5.0</td>
</tr>
<tr>
<td>IR farmer saved</td>
<td>8.3&lt;sub&gt;bc&lt;/sub&gt;d</td>
<td>4.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>51.7</td>
<td>6.0</td>
</tr>
<tr>
<td>Sipindi farmer saved</td>
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<td>4.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>34.7</td>
<td>6.0</td>
</tr>
<tr>
<td>Duma 43 Agro vet</td>
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<td>1.7&lt;sub&gt;c&lt;/sub&gt;</td>
<td>52.8</td>
<td>7.0</td>
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<tr>
<td>Grand mean</td>
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<td>49.6</td>
<td>6.0</td>
</tr>
<tr>
<td>LSD (p=0.05)</td>
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<td>2.0</td>
<td>16.1</td>
<td>1.6</td>
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<tr>
<td>CV%</td>
<td>18.3</td>
<td>25.9</td>
<td>18.5</td>
<td>15.0</td>
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</table>
Table 4.5: Incidence of fungal diseases of seed sources in Busia and Kakamega sites

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Northern leaf blight</th>
<th>Gray leaf spot</th>
<th>Diplodia</th>
<th>Rust</th>
<th>Brown spot</th>
<th>Downy mildew</th>
<th>Eyespot</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Busia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR/Kyongo Agro vet</td>
<td>25.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>0.0</td>
<td>7.9&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>4.4&lt;sub&gt;b&lt;/sub&gt;</td>
<td>3.4&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.0</td>
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<tr>
<td>Sipindi local market</td>
<td>22.7&lt;sub&gt;a&lt;/sub&gt;</td>
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<td>8.5&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.9&lt;sub&gt;b&lt;/sub&gt;</td>
<td>7.8&lt;sub&gt;a&lt;/sub&gt;</td>
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<td>0.0</td>
</tr>
<tr>
<td>Duma 43 farmer saved</td>
<td>22.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>0.0</td>
<td>4.9&lt;sub&gt;bed&lt;/sub&gt;</td>
<td>3.7&lt;sub&gt;b&lt;/sub&gt;</td>
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<td>0.0</td>
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<td>3.0&lt;sub&gt;bed&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.0</td>
</tr>
<tr>
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<td>4.1&lt;sub&gt;cd&lt;/sub&gt;</td>
<td>1.8&lt;sub&gt;e&lt;/sub&gt;</td>
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<td>0.0</td>
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<td>0.0</td>
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<tr>
<td>Duma 43 Agro vet</td>
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<td>1.0&lt;sub&gt;ad&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>1.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>1.9&lt;sub&gt;e&lt;/sub&gt;</td>
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<tr>
<td><strong>Grand mean</strong></td>
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<td>3.2</td>
<td>0.5</td>
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<tr>
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<td>1.9</td>
<td>1.98</td>
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<td></td>
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<td>12.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>21.8&lt;sub&gt;a&lt;/sub&gt;</td>
<td>6.7</td>
<td>3.8</td>
<td>10.4&lt;sub&gt;a&lt;/sub&gt;</td>
<td>4.2</td>
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<tr>
<td>Sipindi local market</td>
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<td>7.1&lt;sub&gt;b&lt;/sub&gt;</td>
<td>10.5&lt;sub&gt;b&lt;/sub&gt;</td>
<td>10.6</td>
<td>3.7</td>
<td>0.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>10.7</td>
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<tr>
<td>Duma 43 farmer saved</td>
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<td>2.3&lt;sub&gt;c&lt;/sub&gt;</td>
<td>6.9&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>5.5</td>
<td>2.3</td>
<td>0.8&lt;sub&gt;b&lt;/sub&gt;</td>
<td>6.1</td>
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<tr>
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<td>4.9&lt;sub&gt;b&lt;/sub&gt;</td>
<td>11.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>3.2</td>
<td>1.1</td>
<td>1.0&lt;sub&gt;b&lt;/sub&gt;</td>
<td>5.9</td>
</tr>
<tr>
<td>Sipindi farmer saved</td>
<td>4.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>7.8&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>4.7</td>
<td>7.7</td>
<td>0.6&lt;sub&gt;b&lt;/sub&gt;</td>
<td>5.6</td>
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<td>Panadol local Market</td>
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<td>2.4&lt;sub&gt;c&lt;/sub&gt;</td>
<td>11.4&lt;sub&gt;b&lt;/sub&gt;</td>
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<td>Panadol farmer saved</td>
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<td>1.6&lt;sub&gt;c&lt;/sub&gt;</td>
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<td>4.6&lt;sub&gt;ab&lt;/sub&gt;</td>
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<tr>
<td>Duma 43 Agro vet</td>
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<td>2.0&lt;sub&gt;c&lt;/sub&gt;</td>
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<td>3.8</td>
<td>10.6</td>
<td>4.9</td>
<td>3.8</td>
<td>2.6</td>
<td>5</td>
</tr>
<tr>
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<td>2.39</td>
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<td>5.64</td>
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<tr>
<td>CV%</td>
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<td>44</td>
<td>103</td>
<td>84.7</td>
<td>132.3</td>
<td>64.1</td>
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</table>
Table 4.6: Severity scores of fungal diseases of seed from the various sources in Busia and Kakamega sites

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Northern leaf blight</th>
<th>Gray leaf spot</th>
<th>Diplodia</th>
<th>Rust</th>
<th>Brown spot</th>
<th>Downy mildew</th>
<th>Eyespot</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Busia</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR/Kayongo Agro vet</td>
<td>1.3</td>
<td>0.0</td>
<td>1.7&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>1.0</td>
<td>0.3</td>
<td>1.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Sipindi local market</td>
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<td>0.0</td>
<td>2.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>1.0</td>
<td>2.0</td>
<td>1.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Duma 43 farmer saved</td>
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<td>0.0</td>
<td>2.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>1.3</td>
<td>1.0</td>
<td>1.3</td>
<td>0.0</td>
</tr>
<tr>
<td>IR/Kayongo farmer saved</td>
<td>1.3</td>
<td>0.0</td>
<td>1.7&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>2.3</td>
<td>1.7</td>
<td>1.0</td>
<td>0.0</td>
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<tr>
<td>Sipindi farmer saved</td>
<td>1.7</td>
<td>0.0</td>
<td>2.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>1.7</td>
<td>2.0</td>
<td>1.3</td>
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</tr>
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<td>0.0</td>
<td>3.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>1.7</td>
<td>1.0</td>
<td>1.0</td>
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<td>Panadol farmer saved</td>
<td>0.7</td>
<td>0.0</td>
<td>2.7&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>1.7</td>
<td>2.0</td>
<td>1.0</td>
<td>0.0</td>
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<tr>
<td>Duma 43 Agro vet</td>
<td>1.3</td>
<td>0.0</td>
<td>0.7&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.3</td>
<td>0.7</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Grand mean</td>
<td>1.4</td>
<td>0.0</td>
<td>2.12</td>
<td>1.4</td>
<td>1.3</td>
<td>1.3</td>
<td>0.0</td>
</tr>
<tr>
<td>LSD (p≤0.05)</td>
<td>1.5</td>
<td>0.0</td>
<td>1.2</td>
<td>1.5</td>
<td>1.7</td>
<td>1.1</td>
<td>0.0</td>
</tr>
<tr>
<td>CV%</td>
<td>63.2</td>
<td>0.0</td>
<td>32.3</td>
<td>63.7</td>
<td>70.6</td>
<td>48.2</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Kakamega</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR/Kayongo Agro vet</td>
<td>3.7&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.7&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.7&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>0.7</td>
<td>0.3</td>
<td>2.0</td>
<td>0.7&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Sipindi local market</td>
<td>3.7&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>2.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>2.3</td>
<td>1.3</td>
<td>1.0</td>
<td>3.0&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>Duma 43 farmer saved</td>
<td>2.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>1.3&lt;sub&gt;c&lt;/sub&gt;</td>
<td>3.3&lt;sub&gt;a&lt;/sub&gt;</td>
<td>1.3</td>
<td>2.0</td>
<td>1.3</td>
<td>2.0&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
<tr>
<td>IR/kayongo farmer saved</td>
<td>2.7&lt;sub&gt;b&lt;/sub&gt;</td>
<td>2.3&lt;sub&gt;b&lt;/sub&gt;</td>
<td>2.3&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>1.0</td>
<td>0.7</td>
<td>1.3</td>
<td>1.3&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Sipindi farmer saved</td>
<td>1.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;d&lt;/sub&gt;</td>
<td>2.0&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>1.7</td>
<td>2.0</td>
<td>1.3</td>
<td>2.0&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
<tr>
<td>Panadol local Market</td>
<td>1.7&lt;sub&gt;cd&lt;/sub&gt;</td>
<td>1.3&lt;sub&gt;c&lt;/sub&gt;</td>
<td>3.0&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>2.3</td>
<td>1.3</td>
<td>2.3</td>
<td>2.0&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
<tr>
<td>Panadol farmer saved</td>
<td>1.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>0.3&lt;sub&gt;d&lt;/sub&gt;</td>
<td>2.0&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>1.7</td>
<td>1.0</td>
<td>1.7</td>
<td>0.7&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Duma 43 Agro vet</td>
<td>2.3&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>0.0&lt;sub&gt;d&lt;/sub&gt;</td>
<td>1.0&lt;sub&gt;c&lt;/sub&gt;</td>
<td>0.3</td>
<td>1.3</td>
<td>1.7</td>
<td>0.7&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Grand mean</td>
<td>2.4</td>
<td>1.5</td>
<td>2.3</td>
<td>1.2</td>
<td>1.3</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>LSD (p≤0.05)</td>
<td>0.8</td>
<td>0.9</td>
<td>1.2</td>
<td>2.0</td>
<td>1.3</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>CV%</td>
<td>19.2</td>
<td>35.1</td>
<td>28.3</td>
<td>98.8</td>
<td>57.0</td>
<td>43.6</td>
<td>52.2</td>
</tr>
</tbody>
</table>

4.4.3 Yield and yield components

At both sites, ears had developed some abnormalities including incomplete kernel tip set, poor tip fill, bouquet ears, exposed ear tip, tassel ear and zipper ear. There were significant variations between the seed sources in ear abnormalities at the two sites. Uncertified seeds from farmer saved and local market had high number of ears having abnormalities at both sites including
incomplete kernel tip set, poor tip fill, bouquet ears, tassel ear and zipper ear, while the certified seeds from agro vet shops had high number of exposed ear tip and ears with extended leaves at both sites (Table 4.7).

There was no significant variation in number of ears per plant in both sites while the result showed significant variation in ear length and grain yield in the two sites. Seeds from agro vet shops were found to have high ear length and grain yield at both sites depending on the variety type. However, Duma 43 from agro-vet shop performed with high ear length and grain yield of up to 6,461 kg ha\(^{-1}\) (Table 4.8).

**Table 4.7:** Ear length and grain yield (kg ha\(^{-1}\)) of various seed sources in Busia and Kakamega sites

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Busia</th>
<th>Kakamega</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ear length</td>
<td>Yield (kg ha(^{-1}))</td>
</tr>
<tr>
<td>Duma 43 Agro vet</td>
<td>21.3(_a)</td>
<td>6,543(_a)</td>
</tr>
<tr>
<td>Panadol farmer saved</td>
<td>18.3(_b)</td>
<td>5,733(_{ab})</td>
</tr>
<tr>
<td>Duma 43 farmer saved</td>
<td>17.8(_{bc})</td>
<td>5,564(_{ab})</td>
</tr>
<tr>
<td>Sipindi local market</td>
<td>17.6(_{bc})</td>
<td>4,956(_b)</td>
</tr>
<tr>
<td>IR farmer saved</td>
<td>17.4(_{bc})</td>
<td>5,407(_{ab})</td>
</tr>
<tr>
<td>Panadol local Market</td>
<td>17.1(_{bc})</td>
<td>6,115(_{ab})</td>
</tr>
<tr>
<td>Sipindi farmer saved</td>
<td>17.1(_{bc})</td>
<td>5,166(_b)</td>
</tr>
<tr>
<td>IR Agro vet</td>
<td>16.5(_c)</td>
<td>3,061(_c)</td>
</tr>
<tr>
<td>Grand mean</td>
<td>17.9</td>
<td>5,318</td>
</tr>
<tr>
<td>LSD (p≤0.05)</td>
<td>1.64</td>
<td>1,203.9</td>
</tr>
<tr>
<td>CV%</td>
<td>5.2</td>
<td>12.9</td>
</tr>
</tbody>
</table>
Table 4.8: Ear abnormalities percentage of seed from various sources in Busia and Kakamega sites

<table>
<thead>
<tr>
<th>Seed sources</th>
<th>Incomplete kernel tip set</th>
<th>Poor tip fill</th>
<th>Bouquet ear</th>
<th>Exposed ear tip</th>
<th>Ear with extended leaves</th>
<th>Tassel ear</th>
<th>Zipper ear</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Busia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sipindi local market</td>
<td>17.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.3</td>
<td>0.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>8.5&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>5.8&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;_b&lt;/sup&gt;</td>
<td>7.8&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Panadol local Market</td>
<td>16.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>24</td>
<td>6.6&lt;sup&gt;_a&lt;/sup&gt;</td>
<td>12.4&lt;sup&gt;_a&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;_b&lt;/sup&gt;</td>
<td>3.4&lt;sup&gt;_d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sipindi farmer saved</td>
<td>12.3&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>18</td>
<td>1.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.7&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.6&lt;sup&gt;_d&lt;/sup&gt;</td>
<td>1.2&lt;sup&gt;_b&lt;/sup&gt;</td>
<td>3.7&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Panadol farmer saved</td>
<td>11.0&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>20.7</td>
<td>3.3&lt;sup&gt;_b&lt;/sup&gt;</td>
<td>10.1&lt;sub&gt;abc&lt;/sub&gt;</td>
<td>5.6&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;_b&lt;/sup&gt;</td>
<td>8.3&lt;sup&gt;_a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Duma 43 farmer saved</td>
<td>10.3&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>18.3</td>
<td>0.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11.4&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>4.6&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;_b&lt;/sup&gt;</td>
<td>4.6&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>IR/kayongo farm sav.</td>
<td>7.0&lt;sub&gt;de&lt;/sub&gt;</td>
<td>18</td>
<td>0.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>7.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.7&lt;sup&gt;_a&lt;/sup&gt;</td>
<td>3.6&lt;sup&gt;_d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Duma 43 Agro vet</td>
<td>4.0&lt;sup&gt;e&lt;/sup&gt;</td>
<td>18.7</td>
<td>0.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7.1&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>6.5&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;_b&lt;/sup&gt;</td>
<td>4.3&lt;sup&gt;_d&lt;/sup&gt;</td>
</tr>
<tr>
<td>IR/Kayongo Agro vet</td>
<td>4.0&lt;sup&gt;e&lt;/sup&gt;</td>
<td>17.7</td>
<td>0.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>9.3&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>9.3&lt;sup&gt;_a&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;_b&lt;/sup&gt;</td>
<td>6.2&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Grand mean</strong></td>
<td>10.3</td>
<td>19.6</td>
<td>1.4</td>
<td>9.6</td>
<td>5.4</td>
<td>0.6</td>
<td>5.2</td>
</tr>
<tr>
<td>LSD (p≤0.05)</td>
<td>4.4</td>
<td>5.4</td>
<td>0.99</td>
<td>3.1</td>
<td>3.3</td>
<td>1.4</td>
<td>1.7</td>
</tr>
<tr>
<td>CV%</td>
<td>24.1</td>
<td>15.8</td>
<td>41.1</td>
<td>18.3</td>
<td>35.3</td>
<td>128.4</td>
<td>18.6</td>
</tr>
</tbody>
</table>

| **Kakamega**                        |                           |               |             |                |                         |           |            |
| Sipindi local market                | 37.9<sup>b</sup>          | 46.2<sup>b</sup> | 8.9        | 15.9<sub>bc</sub> | 10.6<sup>_b</sup>    | 0.0<sup>_c</sup> | 10.7<sup>a</sup> |
| Panadol local Market                | 41.5<sup>a</sup>          | 42.5<sub>bc</sub> | 8.4        | 10.9<sub>cd</sub> | 7.3<sup>_b</sup>     | 0.6<sub>bc</sub> | 4.9<sup>_b</sup> |
| Sipindi farmer saved                | 25.7<sup>d</sup>          | 35.4<sub>c</sub> | 6          | 3.7<sup>e</sup> | 6.4<sup>_b</sup>     | 1.3<sup>bc</sup> | 3.7<sup>_b</sup> |
| Panadol farmer saved                | 29.6<sub>c</sub>          | 54.4<sub>a</sub> | 8.5        | 10.5<sub>cd</sub> | 15.3<sub>ab</sub>    | 0.0<sup>_c</sup> | 10.7<sup>a</sup> |
| Duma 43 farmer saved                | 16.3<sub>e</sub>          | 46.9<sub>ab</sub> | 8.6        | 8.8<sub>de</sub> | 6.9<sup>_b</sup>    | 3.4<sub>_a</sub> | 6.0<sub>ab</sub> |
| IR/kayongo farm sav.                | 36.1<sub>b</sub>          | 48.2<sub>ab</sub> | 5.3        | 21.1<sub>b</sub> | 11.3<sub>_b</sub>   | 1.8<sub>ab</sub> | 2.6<sub>_b</sub> |
| Duma 43 Agro vet                    | 11.8<sub>f</sub>          | 16.6<sub>d</sub> | 3.7        | 27.6<sub>a</sub> | 5.8<sup>_b</sup>    | 1.3<sub>bc</sub> | 1.5<sup>_b</sup> |
| IR/Kayongo Agro vet                 | 11.1<sub>f</sub>          | 17.4<sub>d</sub> | 6.3        | 9.6<sub>d</sub> | 24.9<sub>a</sub>    | 0.0<sup>_c</sup> | 5.2<sub>ab</sub> |
| **Grand mean**                      | 26.3                      | 38.5          | 7          | 13.5           | 11.1                    | 1         | 5.7        |
| LSD (p≤0.05)                        | 3.3                       | 7.42          | 4.75       | 5.9            | 10.7                     | 1.7       | 5.7        |
| CV%                                 | 7.1                       | 11            | 39         | 25             | 55.3                    | 94        | 57.1       |
4.5. Discussion

4.5.1 Emergence and plant lodging

The uncertified seed from local market and farmer saved had high plant establishment while both market and farmer saved seeds highly lodged and counted high number of off-type crops. Dead seeds and rotten seed incidences were higher in certified seeds from agro vet shops. Similar study done by Bishaw et al. (2012) reported a higher level of germination rate in informal seeds compared to certified seeds. FAO (2016b) also reported an isolated case of certified seeds which failed to germinate. This is contrary to the finding of Sperling (2001) and Mahender (2015) who found that informal seeds are usually of low germination potential in field due to low quality.

Also, IRRI (2013) and Coomes et al. (2015) reported that poor seed quality results in uneven seedling stands and more unhealthy seedlings. This is similar to other research by Paplomatas (2006), Niaz and Dawar (2009) which reported that seed quality refers to its ability to germinate.

Mostly, farmer saved seeds are selected from the previous harvest and may be having the probability to emerge faster than the seeds stored for a time. Agro dealer may store their maize seeds for a long time as farmers rely on their own production. Wekesa et al. (2003) observed that improved cultivars do not have good storability compared to landraces, thus certified seeds lose their potential to germinate faster. Adetumbi and Olakoje (2010) also indicated that seed storage is critical for seed quality. It can have an impact on the whole feature of seeds quality attributes and contributes to seed ageing that decreases seed viability. Also, Bennett & Klich (2003) observed that good storage is necessary for seed fitness maintenance. Store environments must remain properly cleaned to prevent leftover contagions from diseased vegetable or seed material saved from previous harvest (Anteneh, 2015).
Seed transmitted diseases constitute the main challenge in the world concerning seed dissemination. They are the most causes of poor performance of the crop from field emergence up to the yield (Du et al., 2001; Rajput et al., 2005; Munkvol and White, 2016; Mueller et al., 2016). In relation to seed testing, storage is important when testing date and planting date are far apart (Rao et al., 2006). Study done by Du et al. (2001), Rajput et al. (2005), Niaz and Dawar (2009), Paplomatas (2006) indicated that seed quality refers to it trueness to it varietal type, physical attribute. Same result was obtained by Sperling (2001) who reported that seeds from the informal system are inappropriate varieties. Badu et al. (2014) also reported that informal seeds do not go through guarantee standards and controlled production networks and therefore could be of poor quality.

Lodging sensitivity of the crops was possibly the effect of seed-borne pathogens observed in the seed samples after laboratory test which reduced resistance to stress due to low vigor. Presence of fungal seed borne pathogens decreases the germination potential and vigor of seeds thus reduces plant development especially when the environment is favorable for disease development (Botelho et al., 2013, Pathak and Zaidi, 2013). Similar study by Badu (2007) also found that recycled seeds are most of the time infected with seed borne pathogens that can reduce crop resistance due to low vigor, can cause lodging, thus lead to low productivity. Poor seed quality results in defective seedling stands and more unhealthy plants in field (IRRI, 2013; FAO, 2009).

4.5.2 Incidence and severity of diseases

Uncertified seeds from farmer saved and local market showed high incidence and severity of fungal diseases though certified was highly susceptible to seedling blight and maize streak virus depending on the variety type. Similar study done by Tonu et al. (2017) found that fungal
diseases intensity was highly expressive in farmer saved wheat than cleaned seeds (Bishaw et al., 2012). There was variation in number of fungal infections in farmer saved and local market seeds and this was highly expressed in Kakamega site. This situation may be explained by environment agro climatic difference whereby Kakamega site is relatively humid than Busia (Appendix 6). This was also confirmed by Badu et al. (2007) who reported that seed borne fungi whereof, are usually severely manifested in an environment with high relative humidity. Fungal diseases develop better in zones with high humidity (Mueller et al., 2016; Munkvold and White, 2016, Wise et al., 2016).

Fungal diseases were more expressed in farmer saved and local market seeds. Common diseases were northern leaf blight, grey leaf blight, rust, brown spot, diplodia, eyespot and ear rots. Though they were observed in all the material, they were severe in the uncertified seeds compared to the seed from agro vet shops. Du et al., (2001), Rajput et al. (2005), Niaz and Dawar, (2009) and Paplomatas (2006) reported that seed-transmitted diseases constitute the main challenge in the world concerning seed dissemination. They are the most causes of poor performance of the crop from field emergence up to the yield. Poor seed quality results in defective seedling stands and more unhealthy plants in the field reducing sensibly production and quality of end product (Dornbos, 1995; Powell et al., 1984; AGRA, 2017; Ali, 2016).

### 4.2.3 Yield and yield components

Farmer saved and local market seeds have developed ear abnormalities including incomplete kernel tip set, poor tip fill, bouquet ears, exposed ear tip, extended ear leaves, tassel ear and zipper ear compared to certified maize seed from the agro vet shops. Peter and Allen (2015) determined that abnormal ears are caused by multiple factors including temperature pressure (cold threat) during initial ear development which can cause bouquet ear; tillers (Suckers) when
the growing point is destroyed or injured by hail, frost, flooding, herbicides, and automated damage can cause tassel ears. Poor ear fill and incomplete kernel tip set can occur when there is poor fertilization of ear tip ovules at silking. It can occur due to inadequate pollen supply caused by uneven crop development, herbicides, insect feeding and foliar diseases (Nielsen, 2006; Nielsen, 2009; Elmore et al., 2006; Thomison, 2007).

Uncertified seeds from farmer saved and local market seeds performed poorly compared to the certified seeds from agro vet shops which performance was dependent on the variety type. The certified Duma 43 from the agro vet shops performed well having low incidence and severity of diseases leading to high yield in both sites. Similar study done by Furtas (2016) and Joshi et al. (2016) indicated that certified seeds of newly developed cultivar are of high yield, diseases confrontation and stresses acceptance (Desalegn, 2017). Also Sperling (2001) reported that farmer seeds are unsuitable varieties, contaminated, the seed quality attributes are below the standards limiting producers’ crop output. Good quality of planting material is crucial for better production. It allows a rational estimation of farm expectation (FAO, 2016; Finch-Savage and Bassel, 2016; Timu et al., 2014; Rodriguez et al., 2015). Mirza (2015) reported that poor quality seed result in skips, excessive thinning or yield reduction diminishing profitability.

Frequent use of seed of unknown quality by agriculture small scale producers results in the decline in maize productivity. On the other hand, Wambugu et al., (2012) gave an option of the view on farmer saved seed that even though farmer seed seems to have its limitation that causes loss in quality and decrease in yield, it also has its strength such as the presence of local varieties/Landraces that are able to perform well under unfavorable conditions. McGuire (2007) added that farmer seed practices in addition to knowledge and social associations are at the heart of tactics not only for filling the lack of seed but also for handling biotic and abiotic stresses.
including diseases, pests and drought. In addition, Seed of open-pollinated variety can be used for more than three years and they retain their genetic characteristics of production (Doss et al., 2003, Spielman et al., 2010). Opposite to the finding of Mueller et al. (2016), Munkvold and White (2016) and Wise et al. (2016) who reported that maize diseases cause important yield loss depending on the disease and the year.
CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 General discussion

Maize production is by small-scale farmers who own land size ranging between 0.5 and 1.5 hectares. Of the interviewed farmers, most of the farmer locates maize on a farm size of less or equal to 0.5ha. This result confirms that maize producers in Busia County cultivate maize on a farm of less than 2ha. The findings of Jayne et al., (2014) and Boone (2015) indicate also that majority of agriculture food producers are small-scale farmers who account for a proportion of 45% in 1994 which rose up to 74% in 2006. Byerlee and Heisey (1997) approved that small-scale farmer in most of the Sub-Saharan Africa regions produce maize crops on land of 0.3 to 0.5 ha.

The majority of farmers rely on farmer saved seeds which are of poor quality, infected with pathogens resulting in poor germination and vigor. Though farmers are aware of improved maize varieties, the adoption of certified seeds remains low due to many reasons among which farmers cited the cost for purchasing seeds also certified seeds are not different from their local materials and not good for consumption. Similar result had been confirmed by Heissey et al. (1998) that majority of small-scale farmers still practice traditional agriculture by using landraces. Also, Opole (2003), Grain (2007), Wekundal (2012), Bremond et al (2013) and Dogbe et al (2014) agreed that a large number of African states rely on seed recycling. In contrast to the finding of Mcguire and Sperling (2016), they indicated that local market constitutes the main source of the seed in SSA. Nevertheless, both farmer saved and local market seeds are among informal seed sources. The reason is that Farmer saved and local market seeds or seeds from informal sector are easier to access at the right time, free exchangeable or low cost (Coomes et al., 2015).
Nyoro (2002) stated that farmers in Western and Central Kenya utilize local varieties and recycle seeds due to lack of confidence in new certified maize seeds from many seed companies in the region.

A large proportion of farmers used farmyard manure while others prefer using simultaneously the compost and DAP. This may be expressed from poor income or lack of credit to farmers or due to poor perception on mineral fertilizers. Nyoro (2002) found that acceptance of fertilizer by small-scale producers is important but not sufficient for crop production, but this should be associated with a reasonable and adequate use. Armyworms and Striga were the actual maize threat in the study area as declared by farmers. Sufficient way for pest management as indicated by maize producers was weeding and soap diluted in tap water which is applied to maize crop. Few farmers used pesticide to fight pests.

Early weeding is among techniques that contribute to fight or reduce the competitiveness of Striga to maize crop. On the other hand, insect pests such as armyworms should be fought using adequate system which mostly is at unaffordable price to farmers. Soil deficiency and ear rots are also major constraints that limited farmers’ expected output. As indicated early before, fertilizer application is not sufficient. This is in agreement with the report from Timothy (2017) who found that application of fertilizer remains low in Kenya even between agriculturalists using complimentary efforts. Shroender et al. (2013), Nyoro (2002) and Muza et al. (2001) also indicated that maximum potential yield of maize should be attained if an optimum level of fertilizer is applied.
Seed quality is an other factor that farmers should know about because seed-transmitted diseases that affect sensibly the expected yield. Since the farmers want to use their local varieties, of uncertified quality, they will permanently gain less output from their field. As stated Timothy (2017), better-quality seeds and fertilizer have important effect on yield and food security. The Agriculture Census in Tanzania (2002/2003) also indicated that few producers who adopted improved varieties of maize and rice associating with fertilizer gained greater productivity compared to those using uncertified seeds. As by the present study, maize production still low with an estimated yield ranging between 200 and 600Kg per hectare. Few farmers who could afford and utilize certified maize seeds, though found with weaknesses, could get yield over 2000kg per hectare.

The study found that though there is a significant difference between the maize seed samples, (p≤0.05), they did not respond to the Kenyan laboratory standard recommending 99% for minimum pure seeds content (Sikinyi, 2010). Nevertheless, Seeds from the major seed distributors including WH 505, WH 507 and Duma 43, had high percentage of pure seed while farmer saved and local market seeds had low pure seeds of 69.9%, and 66.7% respectively. Uncertified seeds were highly contaminated with other variety content than the certified seeds. Seed from local market had high percentage of insect damaged seeds. In view of the physical quality, the certified maize seed was still acceptable for this study regarding the difference in the obtained results after laboratory examination of pure seeds content. This is similar to the finding of Sperling, 2001, Mahender et al., 2015 who indicated that seeds from informal sector are of poor quality, inappropriate varieties and infected seed.

Although there were variations among the seed sources, all the samples meet the recommended germination rate of 90% threshold. Farmer saved and market maize seed had high number of
infected seedlings in contrast to other seed sources. Certified seeds from seed distributors were significantly vigorous compared to farmer saved and local market seeds that competed with the certified seeds from agro vet shops. Fungal seed borne pathogens were isolated from all sources. The non-certified seeds had a high incidence of infected seeds. Farmer saved and local market seeds had a higher number of fungal pathogens than those of certified maize seed from Distributors and Agro vet. Nevertheless, all the seed sources were found with the common pathogens that could have negative impact on production or on consumers including *Fusarium sp*, *Aspergillus sp* and *Penicillium sp*. These pathogens were found over the tolerated level of contamination. This could be due to uncontrolled field conditions, storage period, storability, as farmers appeal on their own stock while certified seeds are stored season to season in seed dealers’ stores that do not respond to the standard of seed storage conditions. As notified by Wekesa et al. (2003), improved varieties do not have good storability, with high cost and more of west quality, susceptible to storing vermin.

Seed sources that had more seed infections were found with poor emergence rate, great number of dead seeds and seed rot including IR/Kayongo from agro vet as presented in table 4.1. In 2007, Badu et al. with similar study found that seed infections reduce plant ability to withstand stresses. Farmer seeds are produced as for ordinary crop production. They are subject to many infections from pests, diseases and cross-pollination from neighboring fields of same species because they don’t follow regulations. These are among reasons why farmer saved and market seeds were having more off-types crops, compared to the certified maize from agro vet. Uncertified maize seeds were highly infected with other maize varieties recognized by their morphology and grain colors. Crops that found to be taller and those observed with high incidence and severities of fungal diseases were the most with high number of stalk lodging. This
is similar to the finding of Badu (2007) who observed that seed borne pathogens lead to decrease of crop resistance, lodging and low productivity. Elmore et al. (2006) and Thomison (2007) who indicated that the poor tip fill and incomplete kernel set which are among the productivity determinant of corn, happen due to deprived fertilization of ear tip ovules at silking, derisory pollen source from uneven plant development, herbicides, pest feeding and foliar diseases. Delouche (1982) precised that about 80% of the amount of the maize seeds used by farmers in western Kenyan counties are from own farm production, as by the study from Louwaar (1994), Dornbos, 1995, Powell et al. (1984) indicated that this kind of seed production seams to ignore certain aspects of seed quality. Consequently, the fall in seed quality and estimated production is looming.

Certified seeds from agro vet sho had resisted diseases though found with a certain incidence and moderate severity of fungal diseases symptoms. Consequently, it performed with largest ears and high yield compare to uncertified seeds from farmer saved and local market. Studies done by Sperling (2001) and Mahender et al. (2015) indicated that uncertified seeds are of poor quality, inappropriate varieties and infected with seed borne disease-causing pathogens, with low germination potential leading to compromised yield. IRRI (2013) also found that unfortunate seed quality results in imperfect seedling stand and more infected crops in the field.

5.2 Conclusion

Majority of the maize producers in Busia County are small-scale farmers who rely on their own farm-saved uncertified seeds. However, most of the farmers are aware of the improved certified maize seeds but still prefer local landraces. Uncertified seeds from farmer saved and local market are of quality attributes, infected seeds with important number of fungal seed-borne pathogens.
They had acceptable levels of germination, vigor index but with higher incidence of infected seeds compared to certified maize seed from the agro vet shops and distributors.

Seeds from farmers and local market had high emergence rate but showed more infected crops in field, with lower vigor, high levels of off types, higher disease intensity level leading to imperfect seedling, susceptible to lodging. Therefore, farmer saved seed may constitute the main foundation of dangerous pathogens and may carry unwanted plants which by time could spread and exacerbate the problem in the environment. The level of contamination of certified seeds from the agro vet was depending on the type of the variety. Certified seed should be of high quality so as to increase adoption by small scale farmers.

5.3 Recommendations

i) Farmers should be sensitized on use of certified seeds accompanied with modern agricultural practices to maximize crop production

ii) There should be integration of adapted local landraces in maize breeding programs

iii) Seed certification agencies should ensure seed security up to the store of agro dealers and make sure agro dealers and farmers are trained on the importance of seed storage and its implication in seed health.

iv) Agro dealers should adhere to the seed regulations on storage, duration and conditions

v) Further research should be conducted on impact of storage, storage period and conditions on seed borne pathogens at agro dealer level.
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APPENDICES

Appendix 1: Survey questionnaire on maize production practices in Busia County of Western in March 2017

Date: ………………………………….

Section I. Background information

1. Farmer’s name: …………………………………………………………Gender: M ☐ F ☐
2. ID Number: …………………………………………………………………………………………………
3. Village ……………………………………………………………………………………………
4. AEZ: ……………………………………………………………………………………………
5. GPS – Latitude: …………………, Longitude: ………………, Elevation: ………………

Section II. Maize production practices

6. Total farm size (acres): ……………………………………………………………………………
7. Acreage under maize (acre): …………………………………………………………………
8. What are the main maize varieties you grow?
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
9. For how long have you been growing the variety?
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
10. Where do you get the seed from?
    …………………………………………………………………………………………………
    …………………………………………………………………………………………………
11. If own seed, where did you get the foundation seed? When?
    …………………………………………………………………………………………………
    …………………………………………………………………………………………………
12. In case of self-saved, when do you harvest?
........................................................................................................................................
........................................................................................................................................

13. Do you intercrop maize with other crops? Yes  □  No □

14. If yes, what are the crops you intercrop with maize
........................................................................................................................................
........................................................................................................................................

15. Do you do crop rotation? Yes  □  No □

16. What was the previous crop on the plot with maize
   a) Last season: ..............................................................................................................
   b) Last 2 seasons: ...........................................................................................................
   c) 3 seasons ago: ..............................................................................................................

17. Do you fertilize maize? Yes  □  No □

18. If yes, which one
   a) Farm yard manures: ...................................................................................................
   b) Fertilizers: ....................................................................................................................
   c) Other: ............................................................................................................................

19. Do you apply fertilizer for top dressing? Yes  □  No □

20. Which one? ...................................................................................................................

21. What do you do with the maize you grow?
........................................................................................................................................
........................................................................................................................................

22. What are the major pests affecting your maize crop?
........................................................................................................................................
........................................................................................................................................

23. How do you manage the pests?
........................................................................................................................................
........................................................................................................................................

24. What diseases affecting your maize crop?
........................................................................................................................................
........................................................................................................................................

25. How do you manage diseases?
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………

26. How many kilograms do you harvest?
   ………………………………………………………………………………………………

27. How do you rank maize crop compare to other crops? ……………………………………….

28. In case of self-saved seed, how do you prepare the seed for planting in term of:
   - Shelling…………………………………………………………………………………..
   - Shelling system……………………………………………………………………………
   - Drying system ……………………………………………………………………………...

29. Do you treat the seed? Yes □ No □

30. How do you store maize seed
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………

31. For how long do you store the maize seed?
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………

32. Do you sort seeds before planting? — Yes □ No □

33. What are the criteria of sorting?
   a) ……………………………………………………………………………………………..
   b) ……………………………………………………………………………………………..

34. Are you aware of improved maize seed?— Yes □ No □

35. Do you use certified seed? ———— Yes □ No □

36. If not, what are the reasons?
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
37. What are the challenges in availability, accessibility in maize seed?
   a) ..............................................................................................................................
   b) ..............................................................................................................................
   c) ..............................................................................................................................

Request for maize seed sample, at least 1 kilogram

Section III: Maize seed traders questionnaire

Trader ID: ..............................................................................................................

Name: .....................................................................................................................

Village/City/: ....................................................AEZ: ..................................................

1. How long have you been in the maize seed business?
   ..............................................................................................................................

2. What maize varieties do you sell?
   ..............................................................................................................................

3. From where do you get the seed sold?
   ..............................................................................................................................

4. If own farm, Where do you get the foundation seed from?
   ..............................................................................................................................

5. Do you intercrop maize with other crops in the seed multiplication field? Yes ☐ No ☐

6. If yes, what are the crops you intercrop with maize
   ..............................................................................................................................

7. Do you do crop rotation for seed multiplication? Yes ☐ No ☐

8. What was the previous crop on the plot with maize
   d) Last season: ........................................................................................................
   e) Last 2 seasons: ...................................................................................................
   f) 3 seasons ago: .....................................................................................................
9. Do you fertilize maize? Yes ☐ No ☐

10. How do you harvest?

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

11. How do you prepare the seed for selling in terms of:
   - Shelling …………………………………………………………………………………
   - Shelling system …………………………………………………………………………
   - Drying system …………………………………………………………………………..

12. Do you dry maize seed after shelling? Yes ☐ No ☐

13. If yes, how do you do it?

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

14. Do you treat the seed? Yes ☐ No ☐

15. If yes, how do you treat them?
   a) Chemical (specify) ………………………………………………………………………
   b) Wood ash …………………………………………………………………………………
   c) Other (specify) ……………………………………………………………………………

16. Do you pack the seed? Yes ☐ No ☐

17. If yes, which size of packaging?
   a) ……………………………………………………………………………………………
   b) ……………………………………………………………………………………………
   c) ……………………………………………………………………………………………

18. For how long do you store your seed?
   a) ……………………………………………………………………………………………
   b) ……………………………………………………………………………………………
   c) ……………………………………………………………………………………………

19. Is your seed certified by the National Seed Service? Yes ☐ No ☐

20. If yes, is your field seed multiplication visited by the seed inspectors? Yes ☐ No ☐

21. What is the origin of the seed you multiply?
   a) ……………………………………………………………………………………………
   b) ……………………………………………………………………………………………
c) …………………………………………………………………………………………………
d) …………………………………………………………………………………………………

22. Who are your major customers?
   a) …………………………………………………………………………………………………
   b) …………………………………………………………………………………………………
   c) …………………………………………………………………………………………………

23. What is the price of your seed (by specifying the size)?
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………

24. How much is the price of maize food of the same size?.................................

25. Have you ever been trained on maize pests and diseases management? Yes ☐ No ☐

26. If yes, what type of training?

<table>
<thead>
<tr>
<th>Type of training</th>
<th>Trainer</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td></td>
</tr>
<tr>
<td>c)</td>
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</tr>
</tbody>
</table>

27. How much seed do you harvest per season?
   a) …………………………………………………………………………………………………
   b) …………………………………………………………………………………………………
   c) …………………………………………………………………………………………………
   d) …………………………………………………………………………………………………

Request for maize seed sample, at least 1 kilogram
Appendix 2: Major diseases of maize observed from the various maize seed sources at Busia and Kakamega experiments

Legends
a. Maize steak virus
b. Northern leaf blight
c. Gray leaf spot
d. Rust
e. Eyespot
f. Diplodia

Maize ear rots
Appendix 3: Culture characteristics and their corresponding conidia view on microscope, isolated from maize seed from various sources in Busia County

Appendix 3. 1: *Fusarium* sp recto and reverse view and corresponding conidia view on microscope
Appendix 3. 2: *Aspergillus sp* recto and reverse view and corresponding conidia view on microscope
Appendix 3. 3: *Penicillium sp* recto and reverse view and corresponding conidia view on microscope
Appendix 4: Maize vegetative growth stage diagram with critical period for production management practices
Appendix 5: Weather data for Kakame County during experimental period

Appendix 6: Weather data for Busia County during experimental period