EVALUATION OF SOURCES OF RESISTANCE TO BLAST DISEASE (*Pyricularia grisea*) IN FINGER MILLET (*Eleusine coracana)* GENOTYPESIN WESTERN KENYA

BY

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DECLARATION AND APPROVAL

Declaration

This Thesis is my original work and has not been presented for the award of any other degree in this or any other university.

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Approval

This Thesis has been submitted with our approval as University Supervisors.

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DEDICATION

I dedicate this thesis to my supportive father Peter Maina, my beloved mother Patister Wanyama, my lovely and wonderful wife Joyce Osoro and our child Jerome Wanyama.

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ABSTRACT

Finger millet (*Eleusine coracana*) is one of the most important cereals in Kenya. Efforts to increase yield production has been hampered by blast disease caused by the fungus *Pyricularia grisea.* The disease affects different aerial parts of the plant at all stages of its growth. The development and use of resistant cultivars has been reported to be the most effective, economical and environmentally sound strategy to control this disease. However, studies indicate that *Pyricularia grisea* exists in various races, thus breaking of resistance of commercial and newly developed varieties frequently. This has led to scientists constantly breeding for new cultivars that are resistant to the ever changing pathogen population. In these study, two experiments were conducted to identify finger millet genotypes that are high yielding and resistant to blast disease. The field study was carried out in two site (KALRO-Kakamega and Alupe) where a hundred diverse varieties (100) were evaluated for blast incidence and severity in a lattice square design for two seasons each (2011-2012). In the second experiment, fifteen field selected finger millet genotypes were planted at Egerton University greenhouse in a completely randomized design (CRD) in 2014. Genotypes were inoculated with the blast pathogen at seedling stage. Data were collected and analyzed by analysis of variance (ANOVA) and means compared using least significant difference (LSD).The results shows that disease severity was highest in early maturing genotypes and lowest in the late maturing genotypes. Both field and greenhouse findings showed that genotype GBK000702, GULU-E, GBK000752, Busibwabo and GBK033575 had general resistance to blast diseases and in contrast, GBK036767, GBK033592, GBK000503 and KNE741were most susceptible to the blast. Genotype GBK033569, Busibwabo and Okhale had the greatest grain yields (2016-2202 kg ha^{-1}), while GBK001119, GBK029713, GBK011127 and GBK000678 were the lowest yielding (652-898 kg ha^{-1}). Pearson correlation analysis between neck severity and physiological maturity was negatively significant (r=-0.47). Also a strong positive correlation between finger severity and neck severity (r= 0.87) was observed. The study found out that blast affects all stages of finger millet growth from seedling through -booting stage to maturity and overall, the most resistant genotypes in all three phases of blast were ACC14, GBK000487, GBK043145, Busibwabo and GBK000752.Theseresistant genotypes would be useful in breeding programs and are recommended for further evaluation to enhance their resistance.

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATION ii
COPYRIGHT iii
DEDICATION iv
ACKNOWLEDGEMENT v
ABSTRACT vi
LIST OF TABLES x
LIST OF PLATES AND FIGURES xi
LIST OF APPENDICES xii
LIST OF ABBREVIATIONS AND DEFINITIONS xiii
CHAPTER ONE 1
INTRODUCTION 1
1.1Background information 1
1.2 Statement of the problem 3
1.3 General objective 4
1.4 Specific objectives 4
1.5 Hypotheses 4
1.6 Justification 4
CHAPTER TWO 6
LITERATURE REVIEW 6
2.1 Finger millet Taxonomy and ecology 6
2.2 Agronomy and economic importance of finger millet 7
2.3. Production constraints 8
2.4 Blast disease management 9
2.4.1 Importance and distribution of *Pyricularia grisea* 9
2.4.2 Biology of Pyricularia grisea 9
2.4.3 Epidemiology of *Pyricularia grisea* 10
2.4.4 Incubation period 11
2.4.5 Pathogen host range 11
2.4.6 Symptomatology and etiology of blast disease 12
2.4.7 Etiology of *P grisea* 13

2.4.8 Survival and dissemination of *P. grisea* 13
2.4.9 Pathogen virulence of *P. grisea* 13
2.5 Control of blast disease: 14
2.5.1 Chemical Control 14
2.5.2 Biological control 15
2.5.3 Cultural control 15
2.5.4 Host-Plant Resistance 16
CHAPTER THREE 18
FIELD EVALUATION OF FINGER MILLET GENOTYPES FORYIELD PERFOMANCE AND RESISTANCE TO BLAST DISEASEUNDER FIELD CONDITIONS 18
3.0 Abstract 18
3.1 Introduction 19
3.2 Materials and methods 20
3.2.1 Site description 20
3.2.2 Plant germplasm 20
3.2.3 Experimental design and treatments 21
3.3 Data collection 21
3.3.1 Data on disease infection 21
3.3.2. Yield and yield parameters 23
3.3.3 Data Analysis. 24
3.4 Results 25
3.4.1. Foliar blast severity and incidence of selected finger millet varieties in Alupe and Kakamega, Kenya (2011/2012) 25
3.4.2: Neck blast disease and neck incidence of selected finger millet varieties in Alupe and Kakamega, Kenya (2011/2012) 28
3.4.3: Finger severity and incidence of selected finger millet varieties in Alupe and Kakamega, Kenya (2011/2012) 32
3.4.4: Effect of plant height and physiological maturity on expression of resistance in finger millet to *Pyricularia grisea* in Alupe and Kakamega, Kenya 35

3.4.5: Genotypic variation for yield and yield traits of test finger millet varieties in Alupe and Kakamega, Kenya (2011/ 2012) 40
3.4.6: Pearson correlation between yield, disease scores and yield components 46
3.5 Discussion 47
3.5.1 Genotypic response to disease infection in the field both sites 47
3.5.2 Genotypic performance of test genotypes in both sites 51
4.0 Conclusion and recommendation 53
4.1 Conclusion 53
4.2 Recommendations 53
4.3 REFERENCE 54
CHAPTER FOUR 64
AVALUATION OF FIELD SELECTED GENOTYPE FOR RESISTANCE TO BLAST UNDER GREENHOUSE CONDITION 64
4.0 Abstract 64
4.1 Introduction 65
4.2 Materials and methods 65
4.2.1 Pathogen and Inoculums preparation 66
4.2.2 Evaluation of inoculated plants for resistance to Blast disease 67
4.2.3 Data Analysis 67
4.3 Results 68
4.4 Discussion 69
4.5 Conclusion 71
CHAPTER FIVE 72
CONCLUSION AND RECOMENTATIONS 72
5.1 Conclusion 72
5.2 Recommendation 72
REFERENCE 74
APPENDIX 76

LIST OF TABLES

TABLE 3.1 A quantitative severity scale for foliar blast disease on finger millet 22
TABLE 3.2: Monthly temperature, rainfall and relative humidity in Alupe and Kakamega 2011/ 2012 24
TABLE 3.3: Mean foliar severity and incidence in Alupe and Kakamega 2011/ 2012 26
TABLE 3.4: Mean neck severity and incidence in Alupe and Kakamega 2011 / 2012 30
TABLE 3.5: Mean finger severity and incidence in Alupe and Kakamega 2011/ 2012 33
TABLE 3.6: Means for Physiological Maturity, Height and Area under disease progress curve in Alupe 2011 and 2012 36
TABLE 3.7: Means for Physiological Maturity, Height and Area under disease progress curve in Kakamega 2011 and 2012 37
TABLE 3.8: Yield performance and yield components traits of selected genotypes in Alupe 2011/2012 42
TABLE 3.9: Yield performance and yield components traits of selected genotypes in Kakamega 2011/2012 43
TABLE 3.11: Correlation coefficient (r) for yield and disease component in Alupe and Kakamega 2011/2012 47
TABLE 4.1: A quantitative severity scale for foliar blast disease on finger millet 67
TABLE 4.2: Reaction genotypes to blast disease under greenhouse conditions. 69

LIST OF PLATES AND FIGURES

PLATE 1: Diseased plant parts with blast symptoms on different plant parts (A: Neck and Finger; B: Leaf) 12
PLATE 2: Leaves showing damage rating (Source: ICRISAT 1997). 22
PLATE 3: panicle showing neck damage rating. Source: ICRISAT 1997. 23
PLATE 4: Foliar blast resistant genotype (GBK033520) (Right) and susceptible (GBK000882) genotype (Left). 28
FIG 1: Finger millet neck blast severity frequency distribution for selected genotypes in Alupe 31
PLATE 5: Neck blast resistant variety (GBK011127) (Right) and a susceptible variety (GBK036767) (Left) 32
PLATE 6: Finger blast susceptible variety that is white and open headed (a) and resistant variety that is compact and dark (b) 35
FIG 2: Graphical interpretation of area under the disease progress curve (AUDPC) in Kakamega season I and II 40
FIG 3: Graphical interpretation of area under the disease progress curve (AUDPC) in Alupe... 40
FIG 4: Yield performance for selected finger millet genotypes in Alupe season I and II 45
FIG 5: Yield performance for selected finger millet genotypes in Kakamega season I and II.... 46
FIG 6: Finger millet foliar blast severity frequency distribution under greenhouse condition. .. 69

LIST OF APPENDICES

APPENDIX 1: List of evaluated finger millet germplasm in Kakamega and Alupe 2011/2012 . 76
APPENDIX 2: Foliar severity scores for 100 finger millet varieties evaluated under field conditions in Kakamega and Alupe 2011 and 2012 77
APPENDIX 3: Neck severity and incidence scores for 100 finger millet varieties under field conditions in Kakamega and Alupe 2011 and 2012 80
APPENDIX 4: Finger severity scores for 100 finger millet varieties under field conditions in Kakamega and Alupe 2011 and 2012 83
APPENDIX 5: Physiological Maturity, Height and Area under disease progress curve in Alupe 2011 and 2012 86
APPENDIX 6: Physiological Maturity, Height and Area under disease progress curve in Kakamega 2011 and 2012 89
APPENDIX 7: Yield and yield component scores for 100 finger millet varieties under field conditions in Alupe 2011 and 2012 92
APPENDIX 8: Yield and yield component scores for 100 finger millet varieties under field conditions in Kakamega 2011 and 2012 95
APPENDIX 9: Analysis of variance (ANOVA) for yield and disease for finger millet varieties in Kakamega, Kenya 2011/ 2012 98
APPENDIX 10: Analysis of variance (ANOVA) for yield and disease for finger millet varieties in Alupe, Kenya 2011/ 2012 99
APPENDIX 11: Analysis of variance (ANOVA) for yield and yield traits for finger millet, Kakamega, Kenya, 2011/ 2012 100
APPENDIX 12: Analysis of variance (ANOVA) for yield and yield traits for finger millet during short rain in Kakamega, Kenya, 2011 100
APPENDIX13: Analysis of variance (ANOVA) for yield and yield traits for finger millet during long rain in Kakamega, Kenya, 2012 100
APPENDIX 14: Analysis of variance (ANOVA) for yield and yield traits for finger millet during short rain in Alupe, Kenya, 2011 101
APPENDIX 15: Analysis of variance (ANOVA) for yield and yield traits for finger millet during long rain in Kakamega, Kenya, 2012 102

LIST OF ABBREVIATIONS AND DEFINITIONS

ABBREVIATIONS

ANOVA	Analysis of variance
AUDPC	Area under disease progress curve'
C R D	Completely randomized design
DNA	Deoxyribonucleic Acid
DF	Days to flowering
DPM	Days to physiological maturity
FAO	Food and agriculture organization
GBK	Gene bank of Kenya
GRH	Grasshopper repeats in *Magnaporthe grisea*
GPCR	G protein coupled receptor
GOK	Government of Kenya
HPR	Host plant resistance
ICRISAT	International crop research institute for semi-arid tropics
RH	Relative humidity
KALRO	Kenya agriculture and livestock research organization
M grisea	*Magnaporthe grisea*
MT	Metric tones
PDA	Potato dextrose agar
P grisea	*Pyricularia grisea*
UV	Ultra violet

DEFINITIONS

Host	A plant that is invaded by a parasite
Inoculum	The pathogen or part of it that can cause infection
Incubation	The time elapsed between exposure to pathogenic organism and appearance of symptoms and signs
Pathogen	An entity that can incite a disease
Pathotype	A disease causing variant of a microorganism. It is distinguishable from other members of its species by its virulence and unique molecular marker
Resistant	Possessing qualities that hinder the development of a given pathogen
Susceptible	lacking the inherent ability to resist attack by the pathogen.
Virulence	The degree of pathogenicity of a given pathogen.

CHAPTER ONE
INTRODUCTION

1.1Background information

Finger millet (*Eleusine coracana* (L.) Gaertn. Ssp. *coracana*) (Hilu *et al.,* 1979) is a small grain crop, which is indigenous to East Africa, especially Uganda and Ethiopian highlands (Haore *et al.,* 2007; Salasya *et al.*, 2009). The crop is especially grown for subsistence in Eastern Africa and Asia (Salasya *et al.*, 2009). The crop is cultivated in diverse eco-geographical areas worldwide and displays high genetic variability (Hilu and de Wet, 1976), indicating that it can be improved through breeding. According to Holt (2000) the crop has wide adaptability, probably due to its C4 photosynthetic nature. Worldwide finger millet production is estimated at 26,702,535tons (FAO, 2009). India is the leading producer (8,810,000tons) which is approximately 33% of world production (FAO, 2009), Eurasia and central Asia (14%), Africa (16%) and the rest of the world (37%). Other major producers are China, Ethiopia, Niger, Nigeria, Mali and Burkina Faso (FAO, 2009). Finger millet accounts for 11 % of production of all millets in the world as compared to 50% pearl millet, 30% Proso millet (Bennetzen *et al.*, 2003; FAO, 2005). In eastern Africa, it is produced in the lake region countries of Uganda, Kenya, Tanzania, Ethiopia, Sudan, Rwanda, Burundi, Congo and Somalia (FAO, 2005). In Uganda, the crop is devoted to about 600,000 ha, while in Kenya it is grown on about 65,000ha (Takan *et al.*, 2002; FAOSTAT, 2008). In Kenya, the crop is grown mostly by smallholder farmers and the main production areas are Western (29%), Nyanza (15%) and Rift valley (13%) (FAO, 2005). This shows that there is a need to increase farmer's yields through improved varieties that are resistant to blast disease.

The crop is a fairly resilient and is drought tolerant and its small grain has an extended shelf life of several years without significant damage by storage pests, thus offers food security opportunities for the rural communities who are small holder farmers. Production trends in Africa and Kenya show a decline mainly due to unimproved cultivars, poor management practices and blast disease (Oduori *et al.,* 2007; Takan *et al.*, 2011). It is especially serious in the Busia and Kisii in Kenya and northern and eastern part Uganda (Mgonja *et al.,* 2007).

Finger millet in East Africa is grown primarily for food in form of thin porridges, malting and brewing unlike India where rarely brewed (Mitaru *et al.,* 1993). Finger millet is being increasingly recognized as a highly nutritious food for the weak and immuno-compromised

people (Takan *et al.,* 2012). The grains is rich in protein, fiber, minerals (calcium, iron, zinc, and manganese) and amino acids (tryptophan, cystine, and methionine), which are crucial to human health and growth that are deficient in most cereals (Malleshi and Klopfenstein 1998). These nutritional elements are also easy to digest. Due to its high nutritive contents, the crop is good especially for pregnant women, lactating mothers, children, the sick and diabetics, (Shasha *et al.*, 2006). It also contains a large proportion of carbohydrates therefore provides bulk of energy in diets.

Despite its economic importance and its resilience, finger millet is affected by several biotic and a biotic constraints. A biotic constraints include drought, low soil fertility, flooding and poor production package (ICRISAT, 2007). Biotic constrains are mainly diseases such as blast, foot rot, smut, leaf blight, Shoot fly, pink stem borer streak and mottling virus (Oduori *et al.,* 2007;Holts, 2000). Amongst these constraints blast caused by heterothallic ascomycete *Magnaporthe grisea* (anamorph: *Pyricularia grisea*) is the most devastating disease affecting different aerial parts of the plant at all stages of its growth (Takan *et al.,* 2012; Srivastava *et al.*, 2009). The Pathogen also causes blast disease in rice and other graminaceaus host (Singh and Kumar, 2010). Average yield loss of around 28 % is usually associated with kernel abortions and shriveled grains caused by damage of panicle during reproductive stage (Sreenivasaprasad *et al.*, 2004; Leen *et al.*, 2007). Under favorable conditions (high temperature, high rainfall and relative humidity) however, blast cause up to 80% losses. Currently most of the land-races and most commercial varieties are susceptible (Sreenivasaprasad *et al.,* 2004).

Since finger millet is an orphan crop grown mainly for subsistence, the disease management by chemical means is not economically feasible thus host plant resistance is the only promising method of blast disease control (Srivastava *et al.*, 2009). Use of resistant varieties is not only economical for minimizing the losses caused by the disease but is also environmentally friendly method. The significance of host resistance and its durability and sustainability in enhancing finger millet production for plant production in all countries and especially developing countries, justifies that breeding and identification of resistance as worthwhile investment.

1.2 Statement of the problem

Although finger millet is an important nutritious cereal crop, it is highly threatened by blast disease which causes up to 80% yield loss under favorable conditions in major growing areas of Western, Nyanza and Rift valley. Most finger millet landraces and commercial cultivars are susceptible to blast and the uses of cultural control methods are limited. Although the use of fungicide is recommended as alternative, it is not feasible due to high cost, environmental and health hazards involved is not economical to small scale-resource poor farmers. Continuous use of fungicides also has potential danger of development of pathogen resistance and possible appearance of new pathotypes of the disease causing higher risk to the crop. Cultural control method is the most ideal but it rarely achieves results because the pathogen is soil borne and spread by water and air infecting large area. Therefore, identification of new sources of resistance especially partial resistance and their deployment are necessary for blast management A lot of efforts have been made towards breeding for resistance to blast by Kenya's finger millet National breeding program, but there has been frequent breakdown of resistance amongst commercial (P224, Kat FM 1, NFM1) and newly developed varieties within a short time of cultivation (Takan *et al.*, 2011). P224 is the highest yielding variety but it is not resistant. Recently released U15 is also not resistant to blast. There is also limited success in identifying cultivars with durable resistance that are high yielding with wide adaptability and stability across varied agro-ecological zones in Kenya. Information on incidence and severity of blast in major growing areas is also limited. In addition, evaluation of finger millet cultivars for resistance to blast is often carried out during vegetative and reproductive stages (adult plant) under field conditions but resistance is deduced from disease severity which is influenced by plant growth habits which is mostly ignored. This study therefore identified potential sources of blast resistance and better yielding genotypes from a composite selection of advanced and breeding lines.

1.3 General objective

The main objective of this study was to improve productivity of finger millet by reducing losses associated with blast disease in major growing areas of Kenya.

1.4 Specific objectives

1. To determine the resistance level of selected finger millet genotypes to blast disease and their yield performance under field condition in western Kenya.
2. To determine the resistance of selected finger millet genotypes against blast disease at seedling stage under greenhouse condition.

1.5 Hypotheses

1. There is no difference in variability for resistance to blast disease and yield Performance in selected finger millet genotypes under field condition.

2. There is no difference in resistance to blast disease among finger millet at Seedling stage under greenhouse condition.

1.6 Justification

Finger millet can be an alternative food security crop in western part of Kenya that is dominated by maize and sugarcane. The crop is highly adapted to dry areas and does well in area with moderate rainfall. The crop is a fairly resilient and is drought tolerant and its small grain has an extended shelf life of several years without significant damage by storage pests, this offers food security opportunities for the rural communities who are small holder farmers. Despite these merits finger millet is not extensively cultivated but is neglected as an orphaned crop. Blast is the most devastating disease in finger millet and most commercial varieties are susceptible therefore planting resistant genotypes that are adapted is the best method in controlling the disease to poor resource farmers. Relationship between the three phase of blast (foliar, neck and finger) in different genotypes of the finger millet is not well documented. The impact of incidence and severity and their importance on yield have also not taken care off. Achievement of the project objectives and dissemination of the outputs to target beneficiaries

and stakeholders will lead to the development and promotion of improved disease management strategies, particularly utilizing host resistance as a mean of combating disease menace in finger millet. The amount of tissue affected in general is a good estimator of the amount of pathogen present. However, severity is not only dependent on the level of resistance of the host cultivar but other factors may interfere such as; earliness in maturity and plant height. Part of this study therefore focused at identifying any relationship between plant height and disease severity and incidence and between plant maturity and disease severity. Adoption of new varieties has in the past led to displacement of local varieties available to farmers which have genetic diversity that can be used as strategy for crop protection thus maintenance must be major consideration in effort to improve the livelihood of poor farmers and as a result local varieties was incorporated in evaluation to blast disease so that partial rather than total displacement of local varieties.

CHAPTER TWO
LITERATURE REVIEW

2.1 Finger millet Taxonomy and ecology

Finger millet is an important subsistence cereal in parts of Africa and South Asia. The species has two subspecies, africana and coracana (L) Gaertn. Subspecies africana has two races, africana and spontanea, while coracana has four races; Elongata, plana, compacta and vulgaris (Prasada *et al.*, 1993). *Eleusine coracana* (L) Gaertn belongs to division Magnoliophyta, Class Liliopsida, Subclass Commelinidae, Order cyperales, Family poaceae (grass family), Genus *Eleusine* Gaertn (goose grass) and species *Eleusine coracana* (L) Gaertn (Jansen and Ong, 1996). Finger millet is an annual growing 40-130cm tall and matures in 2½ - 6 months (Watson and Dallwitz, 1992). Its panicle consists of finger like bisexual spikes with bisexual spikelets and hermaphrodite florets (Watson and Dallwitz, 1992; NRC2, 1996). Finger millet is 97-99% self-pollinating (Hilu and de Wet, 1980; CAB, 2005). The floral architecture and high self-pollination make finger millet difficult to hybridize. Being a C_4 crop is very adaptable to a wide range of environmental and climatic conditions.

The crop has very wide diversity and variability that would benefit breeding programs. Attere, (1993), reported that over 2,500 accessions of finger millet to have been collected in East and Southern Africa. Most of this accessions are found in; Zimbabwe (600), Ethiopia (1,318), Kenya (1,136) and Uganda (2000) (Mushonga *et al.*, 1993). It thrives well at a higher elevation than most other tropical cereals and tolerates salinity better than most cereals. It also grows best in environment with medium rainfall and annual temperature range of 11 to 27°C and a soil pH of 5.0 to 8.2 (Salasya *et al.*,2009). The crop is often intercropped with legumes such as peanut (*Arachis hypogea*), cow peas (*Vigna sinensis*) and pigeon pea (*Cajanus Cajan*) (Singh and Kumar, 2010). Finger millet cultivars are known to vary in height and time of maturity but ear head can be harvested 40 days after flowering to facilitate easy threshing. Harvesting is done manually by cutting ears below the base then dried to 8-9% moisture content for medium-term conservation and 5-7 % moisture content for long term conservation (Jansen and Ong, 1996).

2.2 Agronomy and economic importance of finger millet

In Zimbabwe, seed rates, planting methods, appropriate plant populations, spacing and fertilizer rates have been recommended (Mushonga *et al.*, 1993). Planting in rows is emphasized to facilitate cultivation and Ox-drawn cultivation (Mushonga *et al.*, 1993). In Malawi, recommendations on planting date, planting methods, fertilizer and seed rates have been established (Mnyenyembe, 1993). In Kenya, preliminary work has been done on planting time, plant population, spacing, fertilizer types and rates and planting methods. Early planting at onset of long rain, row planting and spacing of 30cm by 15 cm and application of nitrogen and phosphate fertilizer at planting is recommended (Oduori, 1998).

Finger millet is the most important small millet (Riley *et al.*, 1989), for subsistence and food security and especially for its nutritive and cultural values. As a subsistence and food security crop, finger millet is highly valued as a reserve food in times of famine, due to its good storability property that is a result of its small grain size (Duke, 1978). Grains are used to make fermented drinks while straws are used as animal feeds. According to NRC (1996), the grain's protein content (7.4%) is comparable to that of rice (7.5%), but the main protein fraction (eleusine) has high biological value, with good amounts of tryptophan, cystine, methionine, and total aromatic amino acids, which are crucial to human health and growth which are deficient in most cereals. In addition to better protein profile, it is richer in minerals such as calcium, iron, manganese, and copper than maize (NRC, 1996). On 100g finger millet provides 7.3g protein, 1.3g fats, 3.4g calcium and 3.6g fiber, and in terms of energy, it is estimated to be about 328 K cal (Singh and Kumar, 2010). These qualities make it very effective in controlling blood glucose level and prevent constipation (Singh and Kumar, 2010). The millet diet also releases its sugar very slowly and its fiber content is reported to exclude the incidence of duodenal ulcers in regular consumers (Singh and Kumar, 2010). The high nutritive value gives finger millet some medicinal value, making it an important cereal for community-based health care programs and children feeding schemes in rural institutions in developing countries. For example, it is used in management of measles, anemia, and diabetes (NRC, 1996).The grains however, is considered a course because of its fibrous and tough outer layer that irritates the tongue and thus not readily accepted by people accustomed to the consumption of wheat and

rice. These unique properties of finger millet are shifting the nutritious millet from poor man's grain to the health food of the affluent mostly in large hotels and in cities. It was considered an orphan crop because it has been perceived as the food of the lower socio-economic groups and traditional consumers due to its coarse texture and intense color of seed coat. In Africa is used to make alcohol because its amylase enzymes readily convert starch to sugar, which is subsequently converted to alcohol. In many communities, finger millet has cultural value and it is used in weddings, bride price payment, and funeral ceremonies (Takan *et al.,* 2002).

As a feed, finger millet straw is used as fodder that contains up to 61% total digestible nutrients better than pearl millet, wheat, or sorghum (NRC, 1996). The straw is used for thatching and weaving baskets (Takan *et al.,* 2002).

2.3. Production constraints

The main constraints limiting production of finger millet in Kenya are biotic and a biotic factors. Excessive labor and many of the soils of the marginal areas where finger millet is grown are of low fertility and difficulty in processing non adoption of available technologies like row planting, lack of improved varieties (Oduori, 1993). According to Audi *et al.* (2003) *Striga*, blast disease, low soil fertility, and low yielding varieties are among finger millet production constraints in western Kenya. Poor cultural practices, limited uses, competition from other crops with better economic returns and lack of commercial food products also limits its production (Oduori, 1993). Blast caused by the fungus *Pyricularia grisea* is the most serious disease causing over 50% yield loss (Oduori, 1993). Although pests attack the crop, is not vulnerable to many pests, except shoot fly and stem borers which can be controlled by insecticides. Birds are also a problem especially the notorious *Quelea quelea* and other small grain-feeding birds. Other constraints to finger millet production include poor incentives and low pricing, poor and inaccessible market channels (Oduori, 1993). These constraints together have resulted in farmers attaining only about15% of the 5,000kg ha-1 or above reported by Duke (1978) and the NRC (1996).

2.4 Blast disease management

2.4.1 Importance and distribution of *Pyricularia grisea*

Taxonomically *Pyricularia grisea* is characterized by hyaline septa which can be brown with asci that has one wall and cylindrical with pores. Ascospores have several septa while perithecia is in stroma, immersed in loose hyphae mat, thus pathogen belong to order Diaporthales, class Ascomycetes and phylum Ascomycota. Fungus reproduces by sexual stage (teleomorph) and asexual stage (anamorph) producing sexual spores called ascospore in ascus and asexual spores called conidia on hyphae or on fruiting structure (pycnidia).

The disease has been reported from at least 80 countries growing millet and almost all these are in tropical and temperate part of the world including Africa (Sreenivasaprasad *et al.*, 2004). Japan, India, Malaysia, Uganda, Tanzania, China all have reported incidences of blast as major threat to millet (Oduor and Kanyenji, 2007).

2.4.2 Biology of *Pyricularia grisea*

Pyricularia grisea is identified based on its morphological growth pattern and spore shape. Fungus produces grayish mycelium with conidiophores arising singly or in groups on the diseased part. Conidiophores are slender, straight, grayish and smooth with clusters of conidia that are typically obpyriform, hyaline and 2-4 septate (Singh and Kumar 2010; Getachew *et al.*, 2013). Pathogen is filamentous and is heterothallic with two mating types; MATI-1 and MATI-2 (Srivastava *et al.*, 2009). When fertile isolates carrying opposite types are paired together on appropriate growth medium at 20°c they form fruiting body called perithecia which is flask shaped containing ascospores within 21 days (Talbot, 2003). Pathogen grows on various media in the laboratory producing a dark aerial growth but grows well on host extracts with cardinal temperatures of 25-27°C (Kumar *et al.*, 1999; Sreenivasaprasad *et al.*, 2004). Netam *et al.*, (2013), Jamal *et al.* (2013) and (Getachew *et al.*, 2013) have recorded the best mycelium growth and sporulation of P. grisea on finger millet is at 25 - 30°C According to Srivastava *et al.*, 2009, fructose, mannose, sucrose and glucose are the most useful sources of carbon for the pathogen while nitrogen sources are inorganic nitrate, organic amide and amino nitrogen (Srivastava *et al.*, 2009). Netam *et al.*, (2013) indicated that among the different carbon sources, glucose supported significantly higher mycelial growth, followed by sucrose then galactose. Earlier findings by Valent *et al.*, (1991) and Kumar *et al.*,(2010) reported that *P.*

grisea exhibit wide range of fertility ranging from total sterility through female sterile to full fertility thus is presumed to possess a broad spectrum of variability which is determined possibly by genetic and environmental differences (Takan *et al.*, 2004). Non availability of basic information about the distribution of *P. grisea* impedes the progress of genetic study on variability of blast pathogen and also restricts development of suitable finger millet breeding lines to combat the menace of blast disease in the region (Srivastava *et al.*, 2009). Earlier findings of Purshothaman and Marimuthu (1974) revealed phytoalexin in the infected plants and it is reported to increase when infected leaves are suspended in phenylalanine. It is also perceived to increase the protein content and decreases the starch and glucose content in finger millet while increases activities of ß-glycosidase in the diseased portion (Purshothaman and Marimuthu 1974). *Pyricularia grisea* appressorium is dome-shaped with a highly differentiated cell wall rich in chitin with a layer of melanin on the inner side of the wall acting as an antioxidant that is protective agent from UV rays. It also provides effective means of preventing solute efflux and allows appressoria to accumulate substantial turgor.

2.4.3 Epidemiology of *Pyricularia grisea*

Air and seed spread blast disease pathogen with seed transmission being significant through Seed movement (Kato *et al.*, 2000 and Takan *et al.*, 2004) and according to Pall (1988) one infected seed could cause an epidemic of finger millet blast. The fungus appears to overwinter as mycelia in the infected living leaves or dead plant debris in the soil (Uddin, 2000). High temperature, high relative humidity and leaf wetness are critical environmental factors that influence disease development (Uddin, 2000; Ruiz, 2003). Reports that the disease spreads by seed Kato *et al.*, 2000 and Takan *et al.*, 2004) means that seed selection and hygiene are factors in the control of the disease.

Blast disease is more important in early maturing cultivars (Holt 2000). In similar findings, Eyal and Talpaz, (1990) and Arama *et al.*, (1999) also associated resistance of most pathogens to late maturing cultivars and tall varieties. Asci contain ascospores that are arranged in unordered octads and ascospore are carried from one plant to another plant by dew drops or free waters and germinate within two hours after landing on the leaves by producing germ tube which precedes development of appressorium (Talbot, 2003). Conidia of *P. grisea* usually germinates and produces spores which contain spore tip mucilage (STM) adhesive that allow

binding to the host (Valent *et al.*, 1991). After host binding, appresoria provides mechanical force to penetrate the plant cuticle and gain entry into the internal tissue of the host plant. Pathogen is haploid and reproduces sexually and asexually but infectious life cycle is asexual and conidium is the infectious structure. Environmental factors favoring blast development are temperature of 25-27°C, heavy rainfall and relative humidity of above 85%. Mycelium in the pericarp remains viable at 10°C and 30% RH for at least 8 years (Shasha *et al.*, 2006). The fungus attacks each part of the crop and also causes seedling blight (Viji and Uddin, 2002). The initial inoculum comes from weeds and wild grasses e.g. *Elusine indica, E. africana* and *Dactyloctenium* and collateral hosts, plant debris and shrivelled seeds. Kato *et al.*, (1977) reported that pathogen can be transmitted in seeds and seedlings are the most highly susceptible up to 35 day then resistance develops as plant matures.

2.4.4 Incubation period

Incubation period is the time interval between inoculation and appearance of disease symptoms. Considerable variation exists in reports referring to the duration of incubation period of *P. grisea* from 4 to 6 days (Sreenivasaprasad *et al.*, 2006). Temperature and other environmental factors influence incubation period and this may explain the above differences. High humidity due to rain accelerates infections and continuous rain during ear formation results to heavy losses (Sreenivasaprasad *et al.*, 2006). Incubation period varies also with cultivars and isolates therefore although this parameters may provide valuable information about pathotype, differences may not be used to characterize the pathogen except under highly controlled conditions.

2.4.5 Pathogen host range

Apart from grass, *Pyricularia grisea* have been found to infect finger millet and pearl millet (*Pennisetum glaucum*). The pathogen has also been found attacking rice (*Oryza sativa*), wheat (*Triticum aestivum*) barley (*Hordeum vulgare*), maize (*Zea mays*), Oats (*Avena sativa*), Foxtail millet (*Setaria italica)* and goose grass *(Eleusine indica* (Viji and Uddin 2002; Takan *et al.*, 2002).

2.4.6 Symptomatology and etiology of blast disease

Symptoms of Blast disease occurs in all aerial parts of the plant. Symptoms develop on leaves, neck and on fingers and discolor the grains (Diaz-perez *et al.*, 1996). Symptoms are similar to those of rice blast where the leaf spots are typically elliptical and the shape and color of the spots vary depending on environmental conditions and the susceptibility of the host plant (Leen *et al.*, 2007). Rounded or lenticular spots with a central grey to pale-olive area underneath that extends across the leaf base can also be seen on some varieties. Lesions on a leaf may also coalesce to cause complete drying of leaf or death of the plant but on resistant varieties only minute brown specks of pinhead size may develop. Infection can also take place near the base of one or more 'fingers' which fail to develop further, though the rest of the head grow normally (Takan *et al.*, 2002). Panicle blast (neck and or fingers) is the most destructive phase of the disease and can cause failure of the grain to set and seeds to shrivel. Stem infection causes blackening of the nodal region and maximum damage are caused by neck infection which turns black and shrunken (Plate 1) and an olive-grey growth of fungus are seen on this area (Takan *et al.*, 2002). Infection may also occur at the basal portion of the panicle branches, including the fingers and the affected portions which turns brown and infected ears become generally chaffy and black and a few shriveled grains are formed (Pall, 1994).

A B

PLATE 1: Diseased plant parts with blast symptoms on different plant parts (A: Neck and Finger; B: Leaf)

2.4.7 Etiology of *P grisea*

Hypha is a septate hyaline when young; brown when old with hyphal cells of 1.5-6.0 μm wide and numerous conidiophores and conidia are formed in the center of lesions in humid conditions (Kumar *et al.*, 1999). The conidiophores emerge through epidermal cells or stomata and are straight, sub hyaline at the top and darker at the base. The conidia are hyaline, thin-walled, subpyriform, 3-celled with middle cell darker and broader, formed acrogenously on the sympodial growth of the conidiophores (Pall, 1994).

2.4.8 Survival and dissemination of *P. grisea*

Volunteer plants, off season crops and plant debris have been identified as the most source of inoculums (Talbot, 2003). In absence of living host, *P grisea* can survive for few months on host plant debris under field condition although viability of conidia declines fairly but considerable percentage can survive long enough to infect the crop the following season (Talbot, 2003). Water and air current play a very important role in disseminating the pathogen. Splashing spreads the pathogen from the soil to the stem and leaves thus mulching can reduce the spread of the pathogen. This aspect is important in vertical spread of the pathogen and importance of plant height on expression of resistance. It is possible that viable conidia can be carried over a relatively long distance by air currents and it has also been reported that pathogen can be transmitted by means of infected seeds (Sreenivasaprasad *et al.*, 2006).

2.4.9 Pathogen virulence of *P. grisea*

The pathogen is predominantly a clonally propagating organism, reproducing by conidial production from lesions. Pathogen have six strain: Guy11 that have Mat1-2 mating type, 70-15 with Mat1-1 mating type, P2 with no mating type, K261 with Mat1-2 mating type, K364 with Mat1-2 mating type and 4454-R-1 wild type with Mat1-1 mating type (Talbot 2003). In Europe and America, cultivation is relatively new and dominated by modern plant breeding; the introduction of cultivars carrying exotic resistance genes from numerous genetic backgrounds exerts pressure on the pathogen population such that a few compatible clonal lineages of the fungus predominate (Sreenivasaprasad *et al.*, 2004). Finger millet blast populations containing a repetitive DNA element *grasshopper* (*grh*) have been observed in Japan, Nepal and India as well as in West African countries of Burkina Faso and Mali, but not

in Uganda, Rwanda and Philippines (Sreenivasaprasad *et al.*, 2004). The finding revealed a low-level of *grh* containing blast isolates Africa where finger millet is originated suggesting that the indigenous blast populations did not contain *grh* DNA element. It is likely that germplasm exchanges have led to recent trans-continental movement of the pathogen containing *grh along* with seed material. In Kenya, blast samples collected from Busia, Gucha, Teso, Kakamega and Kisii by ICRISAT found eight genetic groups of the pathogen (Sreenivasaprasad *et al.*, 2004). Some pathogen genotypes were common to both Uganda and Kenya while others were restricted to one country suggesting the need for deploying appropriate resistance sources, taking into account the pathogen virulence diversity (Sreenivasaprasad *et al.*, 2004). The finding showed that the isolates were not genetically distinct suggesting that the same strains are capable of causing different types of blast under suitable agro-ecological conditions (Sreenivasaprasad *et al.*, 2004).

Earlier findings have been shown that the assessment of resistance in crops is done at adult plants. However resistance is deduced from the disease severities that are influenced by plant height and maturity (Eyal and Talpaz, 1990; Arama *et al.*, 1994). It is not known whether resistance expressed in the seedling stage is also reflected in the adult plant stage and vice versa. In contrast, Koch (1990) indicated that all cultivars of rice to *Xanthomonas campestris* showed a general trend towards reduced susceptibility with increasing age. According to Broers and Jacob (1989) in their study in wheat rust reported that partial genes were better expressed in the adult plant stage than in seedling stage. From such studies it is evident that the association between the resistance in the seedling and adult plant stages can vary with particular crop/pathogen system studied.

2.5 Control of blast disease:

2.5.1 Chemical Control

Fungicides been reported to give good control of blast leading to increase in yield. According to Rajashekar *et al.*, (1989), EBP is the most effective seed treatment for *P grisea.* Pall (1994) reported that best control of *P. grisea* and highest yield is obtained with three sprays of Carbendazim 15 days after planting, 15 days later and after flowering. Application of chemicals especially systemic fungicides like azoxystrobin, thiophanatemethyl, trifloxystrobin

and triadimefon, and contact Chlorothalonil are reported to control the disease (Rao and Chennamma, 1983). Findings of Rao and Chennamma (1983) also reported that carbendazim applied at flowering and at milk stage effectively control blast. However, due to high cost of fungicides, lack of expertise and the health hazards involved chemical control hardly a disease control option for small scale famers. It can only be used to a limited extent for example in seed treatment as one of the component of integrated disease management (Talbot, 2003). Fungicides also cause pollution such as residue in food and soil from pesticides, rivers and water contamination from crop spraying. Systemic fungicides are often used to control blast in many rice-growing areas (Talbot, 2003). The use of fungicides with similar modes of action over extensive periods is not recommended because it has resulted in the emergence of resistant populations of the pathogen (Talbot, 2003).

2.5.2 Biological control

Isolates from *Phyllosphere* is reported to reduce growth of the pathogen in culture and suppress spore germination (Sreenivasaprasad *et al.*, 2004).Spray of inoculum on culture is effective in reducing the number of spore on culture. Use of actinomycetes and botanical like Sanna extracts will be of great importance if it proves to reduce or suppress the growth of the pathogen (unpublished).

2.5.3 Cultural control

Appropriate uses of cultural farming techniques would help to reduce reliance to fungicides that are often banned from the market because are toxic to the environment. As a control measure, it is recommended that crop rotation combined with uprooting the millet debris and avoidance of sites adjacent to field in which host plant has recently been harvested can reduce the disease. Intercropping with legumes like pigeon pea, peanut or cow peas reduces intensity of the pathogen (Elsa *et al.*, 2008). Diseased plants debris can be uprooted and burned or composted to prevent the spread of the disease to the next cropping season. For a healthy crop, healthy seeds are necessary during planting. The excessive use of nitrogenous fertilizers promotes luxuriant crop growth which increases the relative humidity and leaf wetness of the crop canopy that favors blast development. The application of silicon fertilizers like calcium

silicate to soils has been reported to reduce blast but is expensive. According to Jena and Mackill, 2008 cheap sources of silicon is found in straws of some genotypes of rice which is economically viable. However the effectiveness of these control strategies is limited due to ability of pathogen to survive in plant debris for a long time and unavailability to practice crop rotation and small scale famers who use their own seeds from previous season. Mulching was reported to reduce infections caused by splashing (Jena and Mackill, 2008).

2.5.4 Host-Plant Resistance

Developing varieties resistant to diseases is one of the aims of plant breeders but yield and quality of the crops are always given priority in most breeding programs. Use of resistant varieties is the traditional disease-management strategy for many plant diseases and the most effective, economical and environmentally friendly for disease control (Holt, 2000; Lenné 2005). In eastern Africa improved varieties have been identified with low blast levels and good agronomic traits (grain yields 1.5-3.0 t ha-1). These varieties include; KNE 688, KNE 814, KNE 1149, P224, Seremi 1, U 15, Gulu E, SEC 915, KNE 409, KNE 1098 (Mgonja *et al.*, 2007a). GULUE has maintained its disease resistance reaction through test seasons and locations. However, there is limited information on the nature of genetic inheritance of genes controlling blast resistance in this variety (Bio-innovate, 2013). Development and introduction of resistant finger millet combined with other disease control practices is the most practical approach of disease control at field level (Holt, 2000). Findings of Upadhyaya *et al.,* 2011) found accessions IE 3392 to be resistant and with rich source of iron (Fe), IE 2957 rich in calcium (Ca) and IE 6537 rich of Ca and protein. The development of finger millet transgenic plants with single gene resistance to foliar blast reported by Latha *et al.,* (2005) promises to contribute to application of host plant resistance in control of finger millet blast disease. Though breeding for resistance is a high priority area of research now, single major gene resistance often breaks down within few years of growing in a conducive environment for the pathogen (Perlevliet, 1988). According to Lin *et al.*, 2007, eight complete resistance genes to blast have been cloned in rice; *Pib, Pita, Pikh,* Pi9, Pi2/*Piz*t, Pid2 *and Pi36*), and *Pi37.* However, reliance on major resistance genes is risky because new pathotypes of the pathogen can evolve rapidly and overcome host resistance (Zeigler *et al.*, 1994). Nonetheless, some resistance genes are found to confer broad-spectrum resistance against pathogen strains tested.

Partial resistance on the other hand, is usually controlled by multiple genes and it may offer a more stable form of resistance (Arama *et al.,* 2004). Partial resistance is a form of incomplete resistance that is largely race nonspecific and polygenic in origin (Arama *et al.,* 2004). According Perlevliet, (1988), incomplete resistant genotype phenotypically is expressed as reduced infectivity and longer latency periods so that the number of lesions developing on partially resistant lines is both reduced and delayed relative to those occurring on more susceptible controls. He noted that genotype with partial resistance also show a continuous range of variation in resistance from extremely susceptible to quite resistant. Four partial-resistance genes in rice have been identified and have been described as specific: *Pif*, *pi21*, *Pb1*, and *Pi34* (Elsa *et al.*, 2008). International Rice Research Institute (IRRI) have also successfully used the MAS based gene pyramiding to transfer four genes *Xa21,xa5,xa4* and *xa13* in elite rice cultivars (Huang *et al.*, 1997).

In India, at Punjab Agricultural University (PAU), three BB resistance genes xa5, xa13 and Xa21 were pyramided in PR106 (Singh, 2009). Findings of Hittalmani *et al.,* (2000) successfully pyramided three genes, *Pi1, Piz5* and *Pita in* a susceptible rice variety Co39 for durable blast resistance to *P. grisea*. Most of the resistant genes are concentrated in certain genomic regions particularly on chromosomes 6, 11, and 12 in rice (Monosi *et al.*, 2004).

CHAPTER THREE

FIELD EVALUATION OF FINGER MILLET GENOTYPES FORYIELD PERFOMANCE AND RESISTANCE TO BLAST DISEASEUNDER FIELD CONDITIONS

3.0 Abstract

Blast has been a continuous threat to finger millet production. The disease is economically important and widespread in finger millet major growing areas of western, Nyanza and Rift valley in Kenya. Host resistance is the most economical and effective means of controlling the disease as finger millet is grown by resource-poor farmers who can't afford the use of fungicides. The study therefore evaluated a hundred finger millet varieties along with two resistant and susceptible (U15 and KNE714 respectively) for resistance to blast at KALRO Kakamega and Alupe, Kenya for two seasons in 2011/2012.A hundred diverse genotypes were evaluated for yield performance and blast incidence and severity in a lattice square design for two seasons. These genotypes had differences in resistance, height, heading dates and phenology. Data were collected and analyzed by analysis of variance (ANOVA) and means compared using least significant difference (LSD) $P < 0.05$). The result shows that disease severity was highest in early maturing genotypes and lowest in the late maturing genotypes. The most resistant genotypes were GBK000702, GBK000513, GBK029869, GBK029875, GULU-E, GBK000752, Busibwabo, and GBK027155. These genotypes could be included in a breeding program for genetic studies on resistance to *Pyricularia grisea*. Genotype GBK033569, Busibwabo and Okhale had the greatest grain yields (2016-2202 kg ha^{-1}), while GBK001119, GBK029713, GBK011127 and GBK000678 were the lowest yielding (652-898 kg ha^{-1}). Resistant check (U15) performed averagely while susceptible check (KNE714) performed poorly in yield. Pearson correlation analysis between neck severity and physiological maturity was positively significant (r=-0.47). Also a strong positive correlation between finger severity and neck severity (r= 0.87) was observed. These tolerant genotypes could be utilized as donor parents for breeding durable blast resistant varieties.

3.1 Introduction

Finger millet is grown in Kenya on about 65,000 ha yr-1, mostly by smallholder farmers (CGIAR 2001). The main production areas are western, Nyanza and Rift Valley (Oduori, 1993). Yields on farmers' fields are generally low about 15% of their theoretical maximum in Kenya (Takan *et al.,* 2002). Finger millet production in Kenya has been declining since 1978 (Mburu, 1989). However, a production figure from Western Kenya which is the largest producer shows variation in production with an average of about 7,700 tons (Mburu, 1989). Despite its economic importance and its resilience, finger millet is affected by several biotic and a biotic constraints. A biotic constraints include drought, low soil fertility, flooding and poor production package (ICRISAT, 2007). Biotic constrains are mainly diseases such as blast, foot rot, smut, leaf blight, Shoot fly (*Atherigona milliaceae*), pink stem borer (*Sesamia inferens*), streak and mottling virus (Oduori, 1998; Holts, 2000). Blast is the most devastating disease affecting different aerial parts of the plant at all stages of its growth (Mgonja *et al.*, 2007; Srivastava *et al.*, 2009). Average yield loss of about 28-36% is usually associated with kernel abortions and shriveled grains caused by damage of panicle during reproductive stage (Sreenivasaprasad *et al.*, 2004; Leen *et al.*, 2007; Nagaraja *et al.*, 2007). Since finger millet is an orphan crop grown mainly for subsistence, the disease management by chemical means is not economically feasible thus host plant resistance is the only promising method of blast disease control (Srivastava *et al.*, 2009). Use of resistant varieties is not only economical for minimizing the losses caused by the disease; it is also an environmentally friendly method. The significance of resistance and its durability for plant production especially in developing countries, justifies that breeding for resistance as top priority. Unlike in other cereals where genetic erosion had been happening with the spread of improved varieties, the danger to the genetic diversity of finger millet a rises not from improved varieties but from their neglect and often replacement with commercial food (Oduori 1998). The objective of this experiment was to evaluate selected finger millet genotypes for resistance against blast disease and determine their yield performance under field condition.

3.2 Materials and methods

3.2.1 Site description

The experiment was conducted in two research stations at Kenya Agriculture and Livestock Research Organization (Kakamega and Alupe) both in western Kenya. Kakamega is located north-east of the Lake Victoria between latitudes of 00° 16'N and longitudes 34° 47'E and falls within the lower humid zone at an elevation of 1800-1900m a.s.l with mean annual precipitation of 2147mm concentrated in two seasons and temperature range of 21-24°C (Jaetzold and Schmidt, 1982).The soils at Kakamega are Dystro- mollic Nitisol with pH of 5.2 (FURP, 1987).

Alupe lies at latitudes of 00° 29'N and 34° 08'E with mean annual temperature of 29.0° C (max) and 15.5°C (min). The area has annual mean rainfall of between 1200-1400 mm. The soils in Alupe are Ferralo-orthic Acrisol with pH of 5.0 (FURP, 1987), Soil is moderately deep with moderate natural fertility and high humus levels (Jaetzold and Schmidt, 1982). The high temperature and high humidity prevalent at Alupe are ideal conditions for the development of the blast pathogen. Western Kenya in general has favorable climatic condition that encourages epidemics and promotes elution of blast. Between the two sites, Kakamega has the highest potential and highest amount of seasonal rainfall, being located in the higher altitude unlike in Alupe with low rainfall and sandy soil infested with striga weed (Jaetzold and Schmidt, 1982).

3.2.2 Plant germplasm

In this study 100 finger millet genotypes were evaluated for high yield and blast resistance (Appendix 1). The genotypes were sourced from KALRO Kakamega, ICRISAT and Gene bank of Kenya. 86 amongst these germplasm were sourced from Gene bank of Kenya, one commercial check (P-224), 10 advanced finger millet lines from KALRO Kakamega and ICRISAT and three local landraces from Western (Ikhulule), Nakuru (Egerton) and Baringo (Koibatek) (Appendix 1). U-15 (resistant check) and KNE 714 (a susceptible check) were included as checks. All germplasm have varied levels of resistance, phenology and maturity. The genotypes were classified based on reaction to infection to pathogen as resistant, moderately resistant and susceptible.

3.2.3 Experimental design and treatments

The evaluation plots was laid out in lattice (10 × 10) design with three replications, A plot comprised of three rows of 2m each spaced at 0.3m apart. Intra-row spacing was 0.15m. The experiment was conducted in two seasons during short season of 2011 (August-December) and long rain 2012 (May-Sept). Both Kakamega and Alupe experiment served to screen for blast resistance and therefore experimental plots used had been previously been planted with finger millet to ensure that plots were sufficiently infested by inoculums. To enhance disease development, two rows of known blast disease susceptible varieties KNE 714 was planted as guard rows to be used as blast disease spreaders. Fertilizer rates of 20kg ha-1 each of D.A.P and C.A.N were applied and the crop kept clean by hand weeding. Five tillers were randomly tagged per plot and disease severities on the tagged tillers were recorded after every 10 days.

3.3 Data collection

3.3.1 Data on disease infection

The following data were taken;

i) Disease incidence was scored on 0-9 scale where 0= no disease and 9 = more than 75% leaf area covered for leaf blast and 0= no disease (all panicles have no disease on neck and finger) and 9 = 81-100% panicles severely infected for neck and finger blast (Plate 2). The three phases of the disease (leaf, neck and finger) were separately scored. Disease incidence scoring for leaf blast was done at seedling and booting stages whereas incidence scoring for finger and neck blast was carried out at physiological maturity and at harvest.

ii) Disease severity rating (% damage) was done on first four leaves (flag). Prior to data recording, at each growth stage five plants in the middle row were tagged randomly and used for disease assessments. The number of plants infected by blast and severity of blast was recorded every 10 days using the modified Cobb scale (Kiran *et al.*, 2012). The scoring of infection type responses and disease severities started when the most susceptible entry showed approximately 5% of disease severity. A total of three recordings were made on Leaf blast severity, using 5 tagged plants from each middle row. Similarly, the assessment of neck and finger blast was done separately on tagged tillers in the two middle rows. The tagging was done to avoid bias. *Pyricularia grisea* severity was evaluated as the percentage of the surface

area infected. The mean disease severity was utilized for the calculation of the Area Under Disease Progress Curve (AUDPC) and terminal severity data were used to compare cultivars.

TABLE 3.1: A quantitative severity scale for foliar blast disease on finger millet

Scores	Reaction category	Appearance of genotypes
1	Very highly resistant	Free from any damage
2	Highly resistant	Less than 10% of the leaves damaged
3	Resistant	11-20% of the leaves damaged
4	Moderately resistant	21 to 30% of the leaves damaged
5	Intermediate	31 to 40% of the leaves damaged
6	Moderately susceptible	41 to 50% of the leaves damaged
7	Susceptible	51 to 70% of the leaves damaged
8	Highly susceptible	71 to 90% of the leaves damaged
9	Very highly susceptible	>90% almost all leaves damaged

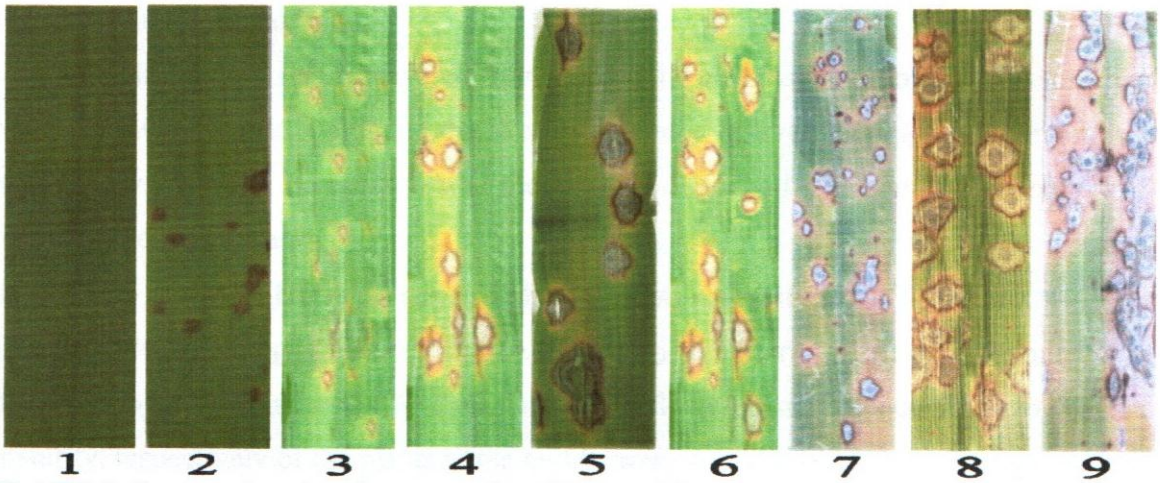

PLATE 2: Leaves showing damage rating (Source: ICRISAT 1997).

iii) Neck blast severity: Based on the relative lesion size on the neck a 1 to 5 progressive rating scale was used where, 1 = no lesions to pin head size of lesions on the neck region, 2 = 0.1 to 2.0 cm size of typical blast lesion on the neck region, 3 = 2.1 to 4.0 cm, 4 = 4.1 to 6.0 cm, and 5 = >6.0 cm size of typical blast --lesion on the neck region (Plate 3). Data were

recorded in field at the physiological maturity on 5 randomly selected and tagged individual plants of each accession.

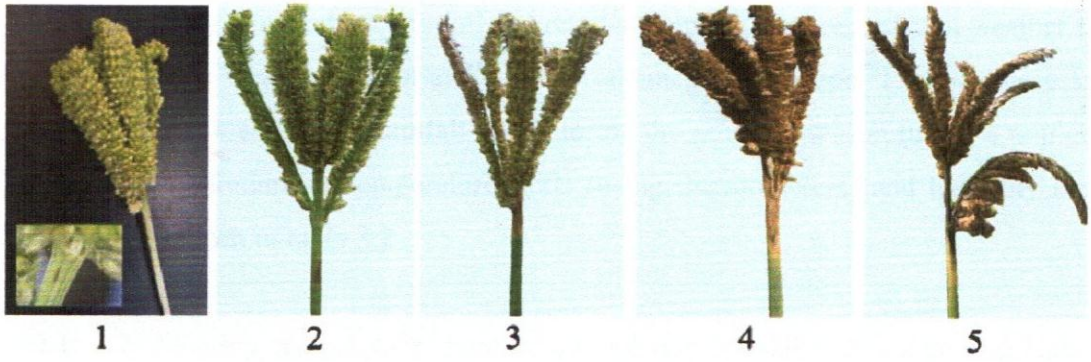

PLATE 3: Panicle showing neck damage rating scale. Source: ICRISAT 1997.

3.3.2. Yield and yield parameters

The following data on yield and yield components was taken on finger millet in the field;

i) Tillers per plant

The number of tillers per plant was determined by physical counting five plants in the middle row picked at random at crop maturity. This was done in all the plots.

ii) Plant height and lodging

Average Plant height (cm) measured from base of the plant to the tip of the spike on five three representative plants in a plot and the average recorded in five plants selected randomly in the middle row. Lodging percentage was the number of lodged plants in a plot expressed as a percentage of plant stands

iii) Days to heading (DH) and days to physiological maturity (PM)

Days to 50% flowering (D50) and days to physiological maturity (PM) were the number of days from planting to when 50% of plants in a plot flowered and reached physiological maturity, respectively of the plants in the middle row.

iv) Grain yields at harvest

At maturity, middle row in each plot were harvested manually in all the plots at the net plot area of $1m^2$ (2m row). The harvested crop was sun-dried, threshed and the seeds cleaned. Threshing was done by use of sticks. Winnowing was done to separate seeds and chaff. The seeds were further sun-dried to moisture content of about 15%. They were then weighed separately and finally the plot yields were used to determine the grain yield (kg/ha).

v) Weather

Data on monthly temperature, rainfall and relative humidity was recorded in weather station using an automatic weather station at KALRO Kakamega and Alupe. This was necessary in determination of the amount of rainfall (mm) during the growing season (using a rain gauge), maximum and minimum air temperatures (°C) (using thermometers) and humidity (using a hygrometer) as shown in table 3.2

TABLE 3.2: Monthly temperature, rainfall and relative humidity in Alupe and Kakamega 2011/ 2012

Kakamega 2011						**Kakamega 2012**					
	Mean temp			**Relative humidity**			**Mean temp**			**Relative humidity**	
Month	**max (oo)**	**min (oo)**	**Rainfall**	**Max (%)**	**Min (%)**	**month**	**max**	**min**	**rainfall**	**Max (%)**	**Min (%)**
AUG	25.8	14.2	233.2	87	61	MAY	26.5	14.9	268.1	83	66
SEP	26.7	14.1	132.1	83	61	JUN	26.5	14.5	212.9	88	57
OCT	27	14.7	193.4	76	60	JUL	25.9	14.1	27.3	89	58
NOV	26.1	15.1	233.9	81	70	AUG	26.3	13.9	281.6	86	60
DEC	27.5	13.9	94.3	75	52	SEP	26.9	13.9	266.4	81	61
JAN	30.1	12	7.7	63	29	OCT	27.4	14.8	142.9	73	63
FEB	31.3	13.8	21	57	27						
	Alupe 2011						**Alupe 2012**				
AUG	29.3	16	9.3	80.8	73.6	MAY	29.1	20.9	10.8	74.9	70.6
SEP	29.5	16.4	12.5	77.3	69.9	JUN	30.5	15.2	12.1	75.3	71.9
OCT	29.2	16.4	5.4	76.6	69.6	JUL	22.1	13.9	6.2	71.4	68.6
NOV	29.4	16.7	12.9	90.1	72.5	AUG	29.2	14.7	4.9	72.5	67.2
DEC	27.1	15.6	9.8	76.8	71.4	SEP	30.7	15.9	9.3	82.4	71.5
JAN	32.1	15.7	7.2	78	73.4	OCT	32.4	15.6	10.8	76	70.8
FEB	34.2	17	2.9	64	57.6						

3.3.3 Data Analysis.

Data were subjected to analysis of variance (ANOVA) using Genstat release 14.1 and treatment means were separated using LSD at $P \leq 0.05$. Simple correlation coefficient (r) was carried out using Pearson's correlation. Homogeneity of error variance was carried out before pooling the data across environments using Bartlett's test for homogeneity. Data on disease scores were transformed by dividing mean response by respective root mean square error for respective environments (Snedecor and Cochran, 1989). Classification of test genotypes for resistance or susceptibility to blast was done based on disease severity (%) and genotypes were

grouped into six categories which included; highly resistant (HR) with < 10% disease infection, resistant (R), 11-30% florets infected, 31-40% florets infected moderately resistant (MR), between 40-50% moderately susceptible (MS), 51-70% florets infected susceptible (S) and 71-100% floret infected as highly susceptible (HS) (Table 3.1 and Plate 2). The blast disease severity scores taken at different times were used to calculate AUPDC of each genotype following Wilcoxon *et al.* (1975) method using the relationship below:

$$AUDPC = \sum_{i=1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i)$$

Where, Xi is the cumulative disease severity expressed as a proportion at the i^{th} observation; t_i is the time (days after planting) at the ith observation and n is total number of observations.

The model for field work: $y_{ijK} = \mu + T_i + \alpha_j + \beta_{jk+} \varepsilon_{ijK}$

i = 1, 2, 3.....100, j = 1, 2, 3 and k=1, 2...10

$Yijk_{=the}$ yield/area under disease for the i^{th} treatment in the k^{th} block within j^{th} rep

μ = Overall mean

T_i = Effect of the i^{th} treatment.

α_j = Effect of the j^{th} rep (superblock)

$\beta_{jk=}$ Effect of the k^{th} incomplete block within j^{th} rep

εijK= Random error effect

3.4 Results

3.4.1. Foliar blast severity and incidence of selected finger millet varieties in Alupe and Kakamega, Kenya (2011/2012).

Results of combined analysis of variance (ANOVA) across seasons in each site are shown in table 3.4 and appendix 2. The findings showed significant genotypic variation for disease incidence and severity ($P \leq 0.05$) (Table 3.3). Genotype and the interactions between genotype and site (G×E), and genotype and season (G×S) (year) affected the disease components of tested finger millet germplasm in the two sites (Table 3.3 and Appendix 2).There was significant difference ($P< 0.005$) in the two seasons and sites in foliar severity thus was need to analyse

TABLE 3.3: Mean foliar severity and incidence in Alupe and Kakamega 2011/ 2012

	Alupe					Kakamega			
	Season one 2011		Season two 2012			Season one 2011		Season two 2012	
Variety	% F sev	F inc	%F sev	F inc	Variety	%F sev	F inc	%F sev	F inc
GBK000621	15.0	2.3	2	2.7	GBK033576	4.0	2.0	6.0	1.6
GBK000865	16.7	2.7	2	1.3	GBK000458	4.7	2.7	11.7	2.3
GBK027076	16.7	2.3	2	1.3	GBK043065	5.0	2.3	5.0	2.0
GBK033520	18.3	2.7	2.3	1.3	IE4115	5.3	2.3	5.0	2.0
GULU-E	18.3	3.0	2	2.0	GBK011125	5.7	2.3	9.3	2.0
GBK000719	20.0	2.3	2.3	2.0	GBK000752	6.0	2.7	11.7	2.7
GBK011098	20.0	2.3	2	1.3	GBK000845	6.0	2.7	5.0	2.0
GBK033605	20.0	2.7	2	1.7	GBK033433	6.0	2.7	6.0	2.0
ACC 29	21.7	2.7	3.7	1.0	GBK033474	6.0	2.3	5.0	2.0
GBK000506	21.7	3.0	5.3	1.7	Okhale-1	6.0	2.3	9.3	2.3
GBK000592	21.7	3.0	2	1.3	GBK000409	6.3	2.7	8.7	2.3
GBK027169	21.7	2.7	4.7	1.7	GBK000487	6.3	2.7	8.7	2.0
GBK029747	21.7	3.0	2	2.3	GBK000696	6.3	2.0	11.7	2.3
GBK033576	21.7	2.7	2	1.3	GBK000815	6.3	2.0	8.7	2.3
GBK011125	23.3	2.8	3.3	2.0	Busibwabo	6.7	1.7	6.0	1.7
GBK011127	23.3	3.0	2	1.3	GBK000449	6.7	2.0	36.7	2.3
GBK043161	23.3	3.0	2.5	2.0	ACC 29	7.0	2.3	6.0	2.3
ACC 14	25.0	3.0	3.3	1.7	GBK000506	7.0	1.7	10.3	2.0
GBK000766	25.0	3.0	4.0	1.3	GBK029819	7.0	2.0	6.0	1.3
GBK029837	25.0	3.0	2.7	1.7	GULU-E	7.0	1.7	6.0	1.3
ACC 32	26.7	3.0	3.7	1.5	GBK029713	7.3	2.3	8.7	2.0
GBK029739	26.7	3.3	2.7	1.7	U-15(RC)	7.3	2.3	7.0	2.0
GBK033575	26.7	3.0	8.7	2.3	ACC 32	7.7	2.3	5.3	2.0
IE4115	26.7	3.0	2.7	1.7	GBK008349	7.7	2.3	5.0	2.0
Ikhulule	26.7	3.0	5.0	1.7	GBK027076	7.7	2.3	4.3	1.7
Okhale-1	26.7	2.7	3.3	1.0	GBK033520	7.7	2.3	5.0	1.7
KNE 714(SC)	41.7	3.7	6.0	2.0	GBK000780	12.3	2.7	10.0	2.3
U 15(RC)	33.3	3.3	3.3	1.8	KNE714(SC)	9.3	2.7	10.0	2.3
RANGE	**8.5-23.8**	**1.7-3.7**	**2-8.7**	**1-3.7**		**5-46.7**	**1.7-3.3**	**4.3-53.3**	**1.3-5**
MEAN	**28.8**	**3.2**	**3.36**	**1.92**		**8.14**	**2.26**	**12.03**	**2.36**
SE	**5.24**	**0.72**	**0.32**	**0.48**		**1.74**	**0.46**	**3.01**	**0.57**
% CV	**18.1**	**22.3**	**25.3**	**25.2**		**21.4**	**20.4**	**25.1**	**24.3**
LSD	**8.43**	**1.17**	**3.66**	**0.88**		**2.80**	**0.74**	**4.86**	**0.93**
Var	***	***	***	***		***	**ns**	***	***
Rep	***	***	***	***		**ns**	**ns**	**Ns**	**Ns**

KEY: Var-variety, *, **, ***-significant at 0.05, 0.01 and 0.001 respectively **F SEV=** Neck severity, **F INC,** Neck incidence, **SC**=susceptible check; **RC**=Resistant check.

each site separately. In Alupe mean foliar severity was higher in season one (28.8%) than in season two (3.6%) (Table3.3). In contrast, average foliar severities were higher in season two than season one in Kakamega (Table 3.3).

In Kakamega season one, out of the a hundred genotypes evaluated, 88 genotypes showed significant resistance to foliar blast with blast incidence scores of < 3.0 and an average severity percentage of <8.1% (Table 3.4). Finger blast incidence mean was 2.26 and ranged between from 1.7 to 3 while percentage severity ranged from 5 to 46.7 % with a mean of 8.14 % (Table 3.3). Genotype GBK033576 (foliar blast incidence 2.0 and severity 4%) and GBK000458 (foliar blast incidence 2.7 and severity 4.7%) had the lowest foliar blast incidence scores and percentage severity. The test varieties KNE714 and U15 had foliar blast incidence (< 3) and percentage severity (< 10) (Table 3.3). In contrast, season two foliar incidence ranged from 1.3 to 5 with a mean of 2.4 and foliar severity ranged from 4.3 to 53.3% (Table 3.3). Genotypes GBK043065 (foliar blast incidence 2.0 and severity 5%) GBK000845 (foliar blast incidence 2.0 and severity 5%) had the lowest foliar blast incidence scores and percentage severity. Busibwabo, Okhale, P224 and Ikhulule had severity less than 10% in season one and two (Table 3.3). Overall in Kakamega the most resistant genotypes wereACC14 and GBK000719 with severity of 9.6 while susceptible genotypes were GBK027169, GBK033410 and GBK043115 with severity of (31.2, 24.3, and 24.2% respectively) (Table 3.3and Appendix 2).

In Alupe season one, the foliar incidence ranged from 1.7 to 3.7 with a mean of 3.2 and severity ranged from8.5 to 23.8 % with a mean of 28.8% (Table 3.3). Resistant check U15 had severity of 33.3% in season one and 3.3% while susceptible check KNE714 had severity of 41.7% and Busibwabo had severity of 33.3 (Table 3.3). Okhale had foliar severity of 26.7% in season one in contrast to season two that had severity of 3.3%. Similar trend was observed with U15 that had severity of 33.3% in season one and 3.3 in season two. In season two incidences ranged from 1 to 3.7 with average mean of 1.92 and severity ranged from 2 to 8.7 with mean of 3.36% (Table 3.3).Resistant check U15 had severity of 3.3% while susceptible check KNE714 had severity of 6% and Busibwabo had severity of 2.3% (Table 3.3). Local genotypes Ikhulule had 26.7 and 5% in season one and two respectively (Table 3.3). Overall in Alupe, most resistant genotypes were ACC14, GBK029713, GBK000414 and GBK000638 with (14.1, 14.1,

14.3, 14.3% severity respectively) while the most susceptible genotypes was susceptible check GBK714 with 23.8 % severity (Table 3.3).

There was generally a higher disease prevalence in Alupe season one than in Kakamega season one unlike in season two where there was higher foliar severity in Kakamega than Alupe. The difference in seasons in each site could be attributed to weather conditions. Combined analysis of the two seasons in each site showed that genotypes ACC14, GBK000487, GBK043145,Busibwabo and GBK000752 were the most resistant genotypes with (11.9,11.9,11.9,12,12% severities respectively). In contrast genotypes GBK033410, GBK027169, GBK000449 and GBK036767 were the most susceptible to foliar blast disease with (22.2, 22.2, 22.2, 21.9% severities respectively (Table 3.3and Appendix 2).Results of this study clearly reveal that among all the genotypes studied, no genotype showed immune response to leaf blast severity. Based on mean foliar blast severity, 88 genotypes were resistant and 12 moderately resistant in Kakamega season one compare to season two with 68 genotypes resistant, 20 moderately resistant and 12 susceptible while in Alupe season two 36 genotypes were moderately resistant and 64 susceptible (Table 3. 3and Appendix 2)

PLATE 4: Foliar blast resistant genotype (GBK033520) (Right) and susceptible (GBK000882) genotype (Left).

3.4.2: Neck blast disease and neck incidence of selected finger millet varieties in Alupe and Kakamega, Kenya (2011/2012).

Results of combined analysis of variance (ANOVA) across seasons in each site are shown in table 3.5.For assessing neck blast severity, a 1-5 rating scale was used based on the lesion size

on the neck region just below the fingers (plate 2) where, (1.0-2.0 = resistant; 2.1-3.0=moderately resistant; 3.1-4.0 = susceptible and 4.1-5.0 = highly susceptible). The analysis indicated significant ($P<0.001$) variation among the germplasm for neck blast reactions in both sites and seasons indicating high variation among the genotypes for neck blast resistance (Table 3.4and Appendix 3). Genotype, and the interactions between genotype and site, and genotype and season (year) affected the neck severity of tested finger millet germplasm (Table3.4and Appendix 3).On average over all growing seasons, the highest mean neck severity were realised in Alupe (5%) compared with Kakamega (4.6%) (Table 3.4 and Appendix 3).

In Alupe, finger millet genotypes were different for resistant to neck blast (Table 3.4 and figure I). Neck blast infection severity was variable from 1 to 5 with a mean of 2.5% (Table 3.5). GBK033592 genotype showed the highest neck blast infection while GBK000503 and GBK027169 genotypes showed a high percentage of neck blast. However, GBK000815, GBK029850 and GBK027076 showed the lowest neck blast infection than resistant control (U15). These genotypes had less neck damage to blast disease (less than 10 %).Neck incidence ranged from 1.7 to 3.7 in season one with a mean of 3.2 (Table 3.4and Appendix 3). In comparison to season two where incidence ranged from 1 to 3.7 with a mean of 4.7 and severity ranged from1 to 5 with mean of 4.4% (Table 3.4and Appendix 3).Based on mean neck blast severity, 43genotypes were resistant (score 1.0-2.0 on a 1-5 scale), 22 moderately resistant (score 2.1-3.0), 18 susceptible (score 3.1-4.0) and 17 highly susceptible (score >4.0) in season one. Figure I show that neck severity was higher in season II than season I Alupe. In season two, 20 genotypes were resistant, 15 moderately resistant, 18 susceptible and 47 highly susceptible. Resistant check U15 was resistant in season one but susceptible in season two compare to susceptible check KNE714 that was susceptible and highly susceptible in season one and two respectively (Table 3.4).Commercial varieties Busibwabo, P222, ACC32, GULU E and Okhale were all resistant in season one but in season two were susceptible and highly susceptible (Table 3.4). Local genotypes lkhulule and Egerton were moderately resistant in all seasons.

TABLE 3.4: Mean neck severity and incidence in Alupe and Kakamega 2011 / 2012

	Alupe					Kakamega			
	Season one		Season two			Season one		Season two	
Variety	Neck sev	Neck inc	Neck sev	Neck inc	Variety	Neck sev	Neck inc	Neck sev	Neck inc
GBK027076	1.0	1.0	1.0	1.0	GBK000815	1.0	1.7	1.3	1.0
GBK040468	1.0	2.0	3.7	1.7	GBK029850	1.0	1.0	1.0	1.7
GBK043065	1.3	2.0	1.7	2.0	GBK027076	1.0	1.0	1.3	1.7
Busibwabo	1.1	2.0	2.3	5.3	GBK000678	1.1	1.3	1.3	1.7
GBK000414	1.1	2.0	3.3	1.7	GBK029713	1.1	1.3	1.0	1.3
GBK000592	1.1	1.0	1.0	2.7	GBK039367	1.1	1.3	6.0	2.3
GBK000696	1.1	1.7	1.7	3.3	GBK043115	1.1	2.0	1.3	2.0
GBK000815	1.3	1.3	5.0	2.3	GBK000458	1.6	2.3	1.3	1.7
GBK011127	1.3	1.0	1.0	2.2	GBK000506	1.6	1.7	1.0	1.3
GBK029869	1.5	2.0	2.3	2.7	GBK029837	1.6	1.3	1.0	1.3
P-224	1.6	2.0	5.0	3.7	Egerton	1.6	1.3	1.0	1.3
GBK000780	1.7	2.3	3.7	4.3	Busibwabo	1.8	2.3	1.0	1.0
Ikhulule	1.7	1.7	2.8	2.7	GBK029869	1.8	2.3	1.0	1.0
Egerton	1.7	2.0	3.3	3.0	GBK033513	1.8	1.7	1.0	1.7
U-15(RC)	1.7	2.3	3.5	3.7	GBK033520	1.8	2.0	1.0	1.0
ACC 32	1.8	2.3	6.3	3.7	GBK033548	1.8	2.3	1.4	1.7
GBK029739	1.8	2.0	1.7	4.0	ACC 14	2.0	1.7	1.0	1.0
GBK033575	1.8	2.0	5.0	3.3	ACC 29	2.0	1.7	1.0	1.3
GULU-E	1.8	1.7	4.7	2.7	GBK000513	2.0	1.7	1.0	1.3
KNE 629	1.8	2.3	5.0	3.0	GBK000780	2.0	2.7	1.0	1.0
Okhale-1	1.9	1.7	2.3	4.3	GBK033605	2.0	1.7	1.0	1.0
GBK000678	2.0	2.3	2.3	5.3	Ikhulule	2.0	1.7	1.3	1.7
GBK000752	2.0	2.7	2.7	4.0	Okhale-1	2.0	2.0	1.3	1.7
GBK011110	2.0	1.7	2.3	3.5	P-224	2.0	1.7	1.0	1.0
GBK033332	2.0	1.0	1.7	4.7	ACC 32	2.1	2.0	1.0	1.3
GBK000458	2.3	2.3	4.8	5.3	IE4115	2.1	2.3	1.0	1.7
GBK000638	2.3	1.3	2.0	4.3	KNE 629	2.1	2.0	1.0	1.3
KNE 714 (SC)	3.7	3.0	5.0	5.2	U 15(RC)	2.6	2.3	1.0	1.0
RANGE	1-5	1.7-3.7	1-5	1-7		1-4.6	1-3.7	1-5	1-6.2
MEAN	2.94	0.58	4.4	4.75		2.3	2.22	1.7	2.0
SE	5.075	26.8	7.22	0.98		4.7	0.45	2.27	0.55
% CV	19.6	0.935	17.8	20.7		20.6	20.6	29	27.4
LSD	0.67	0.9	0.45	0.52		1.03	0.73	0.66	0.88
Var	***	***	***	***		***	***	***	***
Rep	***	***	Ns	***		***	***	ns	Ns

KEY: Var-variety, *, **, ***-significant at 0.05, 0.01 and 0.001 respectively **NECK SEV=** Neck severity, **NECK INC,** Neck incidence, **SC=**susceptible check; **RC=**Resistant check.

Average neck severity in Alupe were greatest in long rain 2012 (4.4%) compared to short rain in2011 (Table 3.4and Appendix 3). This could be attributed to high relative humidity and high temperature during the heading stage.

In Kakamega season one, 41 germplasm were resistant, 47 moderately resistant, 10 susceptible and 2 highly susceptible compare to season two that had 87 germplasm resistant, 3 moderately resistant, 6 susceptible and 4 highly susceptible (Table 3.4 and Appendix 2). Busibwabo, ACC14, ACC29, P224 and ACC32 were all resistant in season one while IE4115, KNE629, KNE714, U15 and GULU E were moderately resistant in season one. However, all commercial varieties were resistant in season two (Table 3.4and Appendix 3).

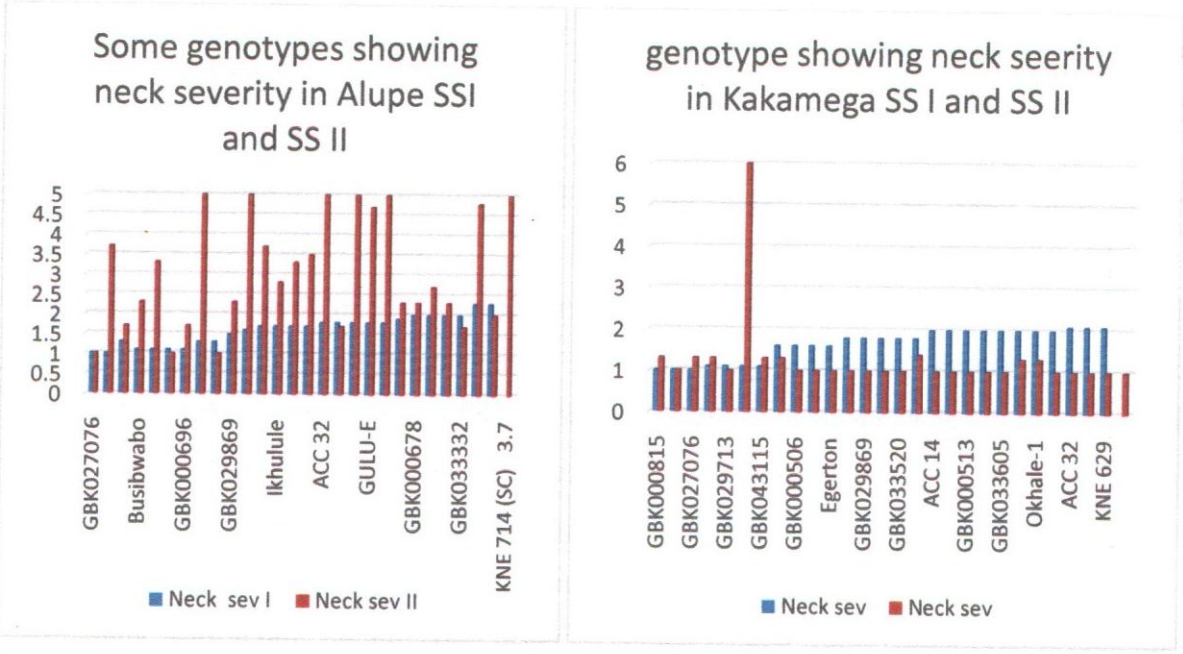

FIG 1. Finger millet neck blast severity frequency distribution for selected genotypes in Alupe and Kakamega

Overall no genotype showed highly resistant reaction to neck blast in all sites. Genotypes GBK027076, GBK000592 and GBK000865 were resistant in Kakamega and in Alupe. Generally disease incidence and severity was high in Alupe than in Kakamega (Appendix 3). The resistant genotypes retained their green color on the neck indicating resistance to the pathogen. On the contrary, the susceptible genotypes succumbed to the pathogen infection and expressed typical blast symptoms (Plate 5).

PLATE 5: Neck blast resistant variety (GBK011127) (Right) and a susceptible variety (GBK036767) (Left)

3.4.3: Finger severity and incidence of selected finger millet varieties in Alupe and Kakamega, Kenya (2011/2012)

Results of combined analysis (Anova) across seasons in each site are shown in table 3.5 and appendix 4. Genotype, and the interactions between genotype and site, and genotype and season (year) affected the finger severity of tested finger millet germplasm (Table 3.5 and Appendix 4). The finger blast severity percentage was classified into resistant (1.0-10%), moderately resistant (10.1-20%), susceptible (20.1-30%) and highly susceptible (>30%).From analyses there was significant difference in the two sites and seasons in finger severity.

In Alupe season one, the infection responses noted ranged from resistant (R) for the immune finger millet to highly susceptible (HS) where the check included in this experiment expressed 93.3% disease severity. Finger severity in season one ranged from5- 63.3% with a mean of 25.12%as compared to season two that ranged from 3.8- 99.3% with a mean of 42% (Table 3.5and Appendix 4).Mean finger incidence for season one was 2.17 while season two was 4.65. This indicated that season two had higher finger severity and incidence than season one which could be attributed to high humidity and high temperature in season two than in season one.

TABLE 3.5: Mean finger severity and incidence in Alupe and Kakamega 2011/ 2012

	Alupe					Kakamega			
	Season one		season two			season one		season two	
Variety	% FiSev	Fi inc	% Fi Sev	Fi inc	Variety	% Fi Sev	Fi inc	% Fi Sev	Fi inc
GBK027076	5.0	1.7	11.7	2.0	GBK039367	5.0	1.3	18.3	2.7
GBK040468	5.0	1.3	53.3	2.3	GBK000506	6.0	1.0	4.0	2.0
GBK043065	8.3	2.0	16.7	3.0	GBK000592	6.0	1.0	3.3	1.7
Busibwabo	10.0	1.7	23.3	2.3	GBK000678	6.0	1.3	3.7	1.3
GBK000414	10.0	2.3	43.3	2.0	GBK000815	6.0	1.7	3.3	1.3
GBK000592	10.0	2.0	8.3.0	2.4	GBK000865	6.0	1.0	2.0	1.0
GBK000696	10.0	2.3	10.0	2.3	GBK011125	6.0	1.0	2.3	1.0
GBK000815	10.0	1.7	33.3	2.7	GBK033513	6.0	1.3	2.0	1.0
GBK011127	10.0	2.0	8.3.0	2.7	GBK043145	6.0	1.0	4.0	2.3
GBK029747	10.0	1.0	10.0	3.0	Okhale	6.0	1.0	3.7	2.0
GBK029850	10.0	1.0	23.3	2.0	GBK011127	6.3	1.3	6.0	2.3
P-224	10.0	2.0	58.3	2.0	ACC 32	10.0	1.3	10.0	3.0
GBK008349	11.7	2.3	11.7	3.0	IE4115	10.0	1.0	3.7	1.3
GBK031890	11.7	2.0	46.7	3.7	KNE 629	10.0	1.0	8.7	2.3
GBK033605	11.7	2.3	16.7	3.0	Egerton	10.0	1.0	2.0	1.0
GBK036839	11.7	2.0	26.7	3.3	ACC 29	11.7	2.0	2.0	1.0
Ikhulule	11.7	2.0	33.3	3.0	Busibwabo	11.7	1.7	1.3	1.0
Egerton	11.7	2.0	25.0	3.7	GBK000409	11.7	1.3	2.67	1.3
U-15(RC)	11.7	2.0	33.3	3.7	GBK000414	11.7	1.3	2.0	1.0
ACC 32	13.3	2.3	60.0	3.3	GBK000458	11.7	1.0	7.0	2.3
GBK029875	13.3	2.0	30.0	3.3	GBK000487	11.7	1.3	11.7	2.3
GBK000361	16.7	1.6	50.0	3.7	GBK000513	11.7	1.3	2.7	1.3
GULU-E	16.7	2.3	46.7	4.3	GBK011098	11.7	1.0	2.0	1.0
KNE 629	16.7	2.3	43.3	3.0	GBK027076	11.7	1.3	6.0	1.3
Okhale	18.3	1.3	28.3	3.3	GBK031890	11.7	2.7	8.7	2.3
GBK000453	50.0	3.7	56.7	8.6	GULU-E	33.3	3.7	6.0	2.0
GBK036767	50.0	1.7	91.7	9.0	KNE 714(SC)	33.3	2.0	23.3	3.7
KNE 714(SC)	31.7	2.7	93.3	6.7	U15 (RC)	16.0	1.3	3.0	1.3
RANGE	**5-63.3**	**1.5-5.8**	**8.3-99.3**	**2.1-9.1**		**5-36.7**	**1.3-4**	**1.3-56.7**	**1-5.6**
MEAN	**25.12**	**2.19**	**42**	**4.65**		**16.76**	**1.8**	**10.3**	**2.16**
SE	**5.75**	**0.53**	**7.08**	**0.99**		**4.08**	**0.48**	**2.99**	**0.53**
CV	**22.9**	**24.4**	**16.9**	**21.4**		**24.4**	**26.4**	**29**	**24.8**
LSD	**5.26**	**0.86**	**9.13**	**0.74**		**6.57**	**0.77**	**4.81**	**0.86**
Variety	***	***	***	***		***	***	***	***
Rep	***	***	**Ns**	**Ns**		**Ns**	**ns**	***	***

KEY: Sea-season, var-variety, *, **, ***-significant at 0.05, 0.01 and 0.001 respectively **SC**=susceptible check; **RC=**Resistant check, **Fi sev**=Finger severity, **Fi Inc** =Finger incidence,

Resistant check U15 had severity of 11.7% in season one and 33.3% in season two while susceptible check KNE714 had severity of 31.7 and 93.3% in season one and two respectively (Table 3.5). Busibwabo had severity of 10 and 23.3% in season one and two respectively while local variety Ikhulule and Egerton had both 11.7% in season one and 33.3 and 25% in season two respectively (Table 3.5and Appendix 4).Based on mean finger severity, 15 genotypes were resistant (score 1.0-10 %), 28 moderately resistant (score 10.1-20%), 22 susceptible (score 20.1-30 %) and 35 highly susceptible (score >30) in season one compare to season two with 5 genotypes that were resistant, 16 moderately resistant, 23 susceptible and 56 highly susceptible. In Kakamega season one genotypes were different in resistance to finger blast (Table 3.5). Finger severity was variable from 5 to 36.7 % with a mean of 16.5% (Table 3.5). Genotypes GBK027169, GBK000503 and KNE714 showed the highest finger blast infection while GBK039367, GBK000506 and GBK000592 showed the lowest finger blast infection. Resistant control U15 had severity of 16% while susceptible check KNE714 had severity of 33.3%.Based on mean finger blast severity scale, 20 genotypes were resistant, 49 moderately resistant, 24 susceptible and 7 highly susceptible.

Kakamega season two had lower finger severity than season one with a mean of 10.08% and ranged from 1.3 to 56.7% (Table 3.6). Based on mean finger blast severity 76 genotypes were resistant, 14 moderately resistant, 4 susceptible and 6 highly susceptible (Table 3.5 and Appendix 3). Resistant check U15 had severity of 3% while susceptible check KNE741 had severity of 23.3% (Table 3.5and Appendix 4).

Overall,average finger severity in Alupe were greatest in long rain 2012 (42%) as compared with short rain 2011 (25.12%) and in contrast to Kakamega where greatest severity was in short rain (16.38%) compare to long rain (10.3%) (Table3.5). Genotypes GBK036767 was Highest susceptible in both sites. Genotypes producing dark colored seeds and compact (fist) heads were more resistant to blast compared to white-seeded and open-headed genotypes (Plate 6). The genotypes identified can be utilized in breeding programs and some could be promoted for farmer productions.

a) White and open headed b) Dark Colored and compact variety

PLATE 6: Finger blast susceptible variety that is white and open headed (a) and resistant variety that is compact and dark (b)

3.4.4: Effect of plant height and physiological maturity on expression of resistance in finger millet to *Pyricularia grisea* in Alupe and Kakamega, Kenya

AUDPC is a good indicator of adult plant resistance under field condition (Wang *et al.*, 2005). Genotypes which had low AUDPC and terminal severity values may have good level of adult plant resistance (Wang *et al.*, 2005). There was statistically significant ($p<0.001$) difference among the test genotypes with regard to their AUDPC values. AUDPC, PM, and HT appeared to associate with each other and the linear correlation coefficient (r) between AUDPC and HT, AUDPC and PM and HT were -0.26, -0.75 and -0.03 respectively. Table 3.7 and 3.8 gives the data for some entries that represent the range of variation for PM, HT and relative AUDPC in the two sites. A multiple regression equation was derived from the data observed AUDPC for the effects of HT and PM. The equation derived was; AUDPC=1525-2.181HT-10.798PM. Physiological maturity and plant height had effect on AUDPC where the short and early maturing genotypes appeared more susceptible than tall and late maturing genotypes. The genotypes which recorded higher AUDPC values showed severe necrotic lesions of the foliage. In Alupe season one there was significant difference between genotypes with values of area under the disease progress curve (AUDPC) varying from 126 to 402 for leaf blast (Table 3.6and Appendix 5). GenotypeGBK011098 had the lowest AUDPC (146) value compared to KNE714 with 402.Considering AUDPC as a measure of disease severity, genotypes GBK0000621, GBK036839, GBK033605GBK011098, GBK000719, GBK000865,

TABLE 3.6: Means for Physiological Maturity, Height and Area under disease progress curve in Alupe 2011 and 2012

			ALUPE SEASON ONE				ALUPE SEASON TWO			
Variety	**PHT**	**DM**	**FSEV 1**	**FSEV 2**	**FSEV 3**	**AUDPC**	**FSEV 1**	**FSEV 2**	**FSEV 3**	**AUDPC**
GBK011127	54.0	109	2.0	6.0	25.0	195	2.0	2.0	2.0	40
GBK000590	57.0	96	2.3	5.3	28.3	206	3.7	3.0	5.3	75
GBK000621	63.0	106	2.3	4.3	20.0	155	2.0	2.0	2.0	40
GBK008349	67.0	105	2.3	8.3	25.0	220	4.3	1.7	4.7	62
GBK011098	60.0	99	2.3	4.3	18.3	146	2.2	2.0	3.5	49
Ikhulule	77.0	105	2.3	5.3	26.7	198	1.7	3.0	5.0	64
GBK000359	67.0	96	2.7	7.7	40.0	291	2.3	2.3	3.3	51
GBK000503	60.0	90	2.7	6.0	28.3	215	2.7	4.3	5.7	85
GBK000592	61.0	113	2.7	7.3	21.7	195	2.0	1.7	2.0	37
GBK000719	68.0	104	2.7	5.7	20.0	171	3.3	2.7	2.7	57
GBK000815	58.0	107	2.7	5.0	23.3	180	3.0	1.7	3.3	49
GBK000865	71.0	107	2.7	6.7	16.7	164	4.0	1.3	2.0	43
GBK001119	51.0	97	2.7	6.7	35.0	256	9.0	2.0	4.0	85
GBK011110	68.0	105	2.7	6.7	28.0	221	2.0	1.3	2.3	35
GBK029739	70.0	105	2.7	6.3	26.7	210	2.0	2.7	2.7	51
GBK031861	64.0	100	2.7	6.3	30.0	227	4.3	2.3	2.7	58
GBK031890	75.0	104	2.7	7.0	30.0	234	1.7	2.0	2.3	40
GBK033433	69.0	104	2.7	6.0	26.7	207	2.0	2.0	4.3	52
GULU-E	66.0	102	2.7	7.0	18.3	175	1.7	2.3	2.0	42
U-15 (**RC**)	65.0	95	2.7	6.3	33.3	243	2.7	1.7	3.0	46
ACC 29	66.0	100	3.0	6.7	21.7	191	3.7	2.0	3.7	57
ACC 32	69.0	101	3.0	6.0	26.7	209	1.7	1.3	3.7	40
Busibwabo	76.0	100	3.0	6.7	33.3	249	2.3	1.7	2.0	39
Egerton	77.0	102	3.0	10.0	35.0	290	2.0	1.7	2.3	39
Koibatek	75.0	100	3.3	7.7	35.0	269	2.7	1.7	4.7	54
ACC 14	69.0	105	3.7	7.7	23.3	212	1.7	1.7	3.3	42
KNE 629	68.0	103	3.7	6.3	30.0	232	2.7	2.7	5.0	66
Okhale-1	65.0	103	3.7	11.3	26.7	265	4.3	2.0	3.3	58
P-224	63.0	101	3.7	7.7	31.7	254	1.7	4.0	3.0	64
IE4115	63.0	98	4.0	11.7	26.7	271	2.3	2.0	2.7	45
KNE 741 (**SC**)	58.0	89	4.0	17.3	41.7	402	2.0	4.7	6.0	87

KEY: **PHT**=Plant height, **DM**=Days to maturity, **FSEV1**= Foliar severity I, **FSEV2**= Foliar severity 2, **FSEV3**= Foliar severity 3, **AUDPC**=Area under disease progress curve

TABLE 3.7: Means for Physiological Maturity, Height and Area under disease progress curve in Kakamega 2011 and 2012

KAKAMEGA SEASON ONE							KAKAMEGA SEASON TWO			
Variety	PHT	DM	**FSEV1**	**FSEV2**	**FSEV3**	AUDPC	**FSEV 1**	**FSEV2**	**FSEV3**	AUDPC
GBK000458	54	114	2.0	3.0	4.7	64	11.7	5.0	2.3	120
GBK011125	71	118	2.0	3.0	5.7	69	9.3	6.7	3.0	129
GBK043065	75	111	2.0	3.0	5.0	65	5.0	4.7	2.0	82
ACC 14	84	116	2.3	3.7	10.0	99	9.3	6.7	3.0	129
Busibwabo	76	111	2.3	3.3	6.7	78	6.0	4.0	1.7	79
GBK000463	79	109	2.3	3.3	9.0	90	15	8.0	2.7	169
GBK000487	62	117	2.3	4.7	6.0	89	8.7	4.3	1.7	95
GBK000608	60	111	2.3	3.3	7.3	81	7.0	7.7	2.7	126
GBK000845	67	112	2.3	3.3	5.7	73	5.0	5.3	2.3	90
GBK008349	78	111	2.3	3.3	7.7	83	5.0	5.0	1.7	84
GBK027076	58	120	2.3	3.3	7.7	83	4.3	4.3	1.7	73
GBK028567	55	104	2.3	3.3	7.0	80	31.7	19.3	7.7	390
GBK029869	65	116	2.3	3.3	6.7	78	6.0	5.7	3.0	102
GBK029875	73	112	2.3	3.0	7.0	77	6.0	4.3	2.3	85
GBK033433	71	119	2.3	3.7	6.7	82	6.0	6.0	2.3	102
GBK033513	68	125	2.3	3.7	7.0	84	9.3	6.7	2.3	125
GBK033551	64	112	2.3	3.7	7.7	87	7.7	3.0	1.3	75
GBK043145	81	111	2.3	3.0	7.0	77	8.7	7.0	2.3	125
GULU-E	62	112	2.3	3.7	7.0	84	6.0	4.7	1.7	86
IE4115	57	113	2.3	3.0	5.3	68	5.0	4.7	2.0	82
P-224	64	111	2.3	3.3	8.0	85	7.7	8.3	3.0	137
ACC 29	63	119	2.7	3.7	7.0	86	6.0	6.3	3.3	110
GBK000359	79	110	2.7	4.0	8.0	94	9.3	7.0	2.7	130
GBK000364	78	112	2.7	3.3	8.0	87	7.0	6.0	2.7	109
KOIBATEK	79	111	2.7	3.7	9.7	99	11.7	9.3	3.3	168
NAKURU	80	117	2.7	3.3	10	97	7.0	6.0	2.7	109
Okhale-1	70	110	2.7	4.0	6.0	84	9.3	6.0	1.7	115
U-15	60	108	2.7	3.3	7.3	83	7.0	9.0	4.0	145
GBK000409	69	111	2.8	3.7	8.0	91	8.7	7.3	3.3	133
ACC 32	78	115	3.0	4.0	8.7	99	5.3	5.7	2.0	94
KNE 629	64	113	3.0	3.7	9.7	101	6.0	4.3	2.0	83
KNE 741	65	112	3.0	5.0	9.3	112	10.0	8.7	3.0	152
Ikhulule	75	114	3.3	3.3	8.0	90	9.3.0	10.7	4.0	174

KEY: **PHT**=Plant height, **DM**=Days to maturity, **FSEV1**= Foliar severity I, **FSEV2**= Foliar severity 2, **FSEV3**= Foliar severity 3, **AUDPC**=Area under disease progress curve

GBK043124 and GULU E were superior in resistance as characterized by low range for AUDPC (146- 175 (Table 3.6and Appendix 4).It shows these genotypes have high level of resistance to foliar blast. These genotypes can be used as donor parents for breeding stable resistant varieties to blast. Susceptible check KNE714, GBK033548 and GBK000882 on the other hand, were the most susceptible and showed a high range for AUDPC (303-402) (Table3.6). Genotypes with highest AUDPC value had higher level of susceptibility to foliar blast (Table 3.6 and Appendix 5). Commercial varieties ACC14, GULU E, IE4115, P224, ACC29, ACC32 and KNE629 were moderately resistant with AUDPC of 212, 175, 271,254, 191, 209 and 232 respectively (Table 3.6). The high AUDPC value recorded for the three genotypes (KNE714, GBK033548, and GBK000882) is a reflection of their degree of susceptibility to blast prevailing in Alupe. The susceptibility of P224 and U15 indicates the potential threat in wiping out the high yielding varieties currently under commercial production.

From the second season, the genotypes GBK043161, GBK043258, GBK029837, GBK029850, GBK033551, GBK033332, GBK043065, GBK039367 and Busibwabo showed a good level of resistance to foliar blast. They were characterized by reduced range for AUDPC (35-39). Contrary, Susceptible check KNE714, GBK0000845, GBK033575, GBK001119 and GBK000503 on the other hand were the most susceptible with increased range of(81-97) (Table3.6). Commercial varieties ACC14, GULU E, IE4115, P224, ACC29, ACC32 and KNE629 had AUDPC of 42, 42, 45,64, 57, 40 and 66 respectively (Table 3.6).

In Kakamega season one, the genotypes GBK000458, GBK043065, GBK033576, GBK011125, and IE4115 showed a high level of resistance to foliar blast as characterized by low range for AUDPC (64- 69) (Table 3.7and Appendix 6). Genotype GBK033410, GBK000513, GBK033569, GBK011098, GBK000780 and GBK043169 on the other hand were the most susceptible and showed increased range for AUDPC (120-150) (Table3.7). Susceptible check KNE714 and Resistant check U15 had 112 and 83 respectively (Table 3.7). Commercial varieties ACC14, GULU E, IE4115, P224, ACC29, ACC32 and KNE629 had AUDPC of 99, 84, 68, 85, 86, 99 and 101 respectively (Table 3.7 and Appendix 5).

In Kakamega season two, the genotypes GBK027079, GBK033551, GBK011127, GBK033605, and Busibwabo were more resistant to foliar blast with low range for AUDPC (73- 79). Genotypes GBK027169, GBK000882, GBK000503 GBK040468, GBK036767 and

GBK000904 were the most susceptible and showed a high range for AUDPC (479-588) (Table3.7). Susceptible check KNE714 and Resistant check U15 had 152 and 145 respectively (Table 3.7). Commercial varieties ACC14, GULU E, IE4115, P224, ACC29, ACC32 and KNE629 had AUDPC of 129, 86, 82, 137, 110, 94 and 82respectively (Table 3.7 and Appendix 5).GBK000882, GBK000503, GBK036767 and GBK040468 were the most susceptible to blast infection as depicted by the high AUDPC and terminal severity value. Even though the yield obtained from some of these genotypes are high, their current susceptibility to blast is a warning to the potential risk associated with the continuous production of these cultivars. Thus, a breeding program should be devised to cross the high yielding susceptible genotypes with resistant genotypes such as GBK000361, GBK027076 and GBK033605 that has low AUDPC and terminal severity.

Results that are summarized in Table 3.8 and Figure 2 indicate that AUDPC of the tested Genotypes were highest in season two compared to season one. The lowest AUDPC values for test genotypes were GBK011127, GBK000621, GBK000865, GBK000696, GBK000592 and GBK033513 and their terminal severity were also small and ranged from 5MS-20MS. This shows that these genotypes have good level of adult plant resistance to blast and can be used as resistance sources. On the other hand, most of the high yielding genotypes such as Busibwabo, P224,Okhale and IE4115 were moderately resistant to blast under field condition as their AUDPC value were relatively low compared to the susceptible check. Field resistance is assumed to be of quantitative nature and thus expected to be durable. Disease severity and area under disease progress curve (AUDPC) in particular are reliable estimators of partial resistance and have been used in studying durable resistance in wheat (Royle *et al.*, 1986). A good negative correlation between AUDPC and height were demonstrated to exist. Varieties with low AUDPC and low severity could be used as source of resistance in the breeding program.

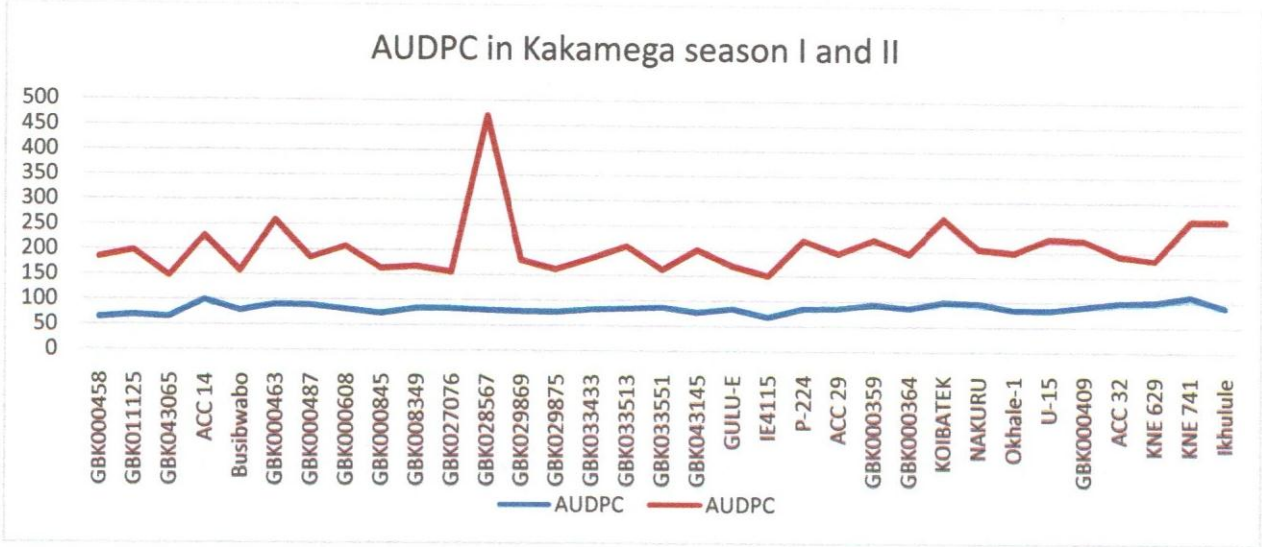

FIG 2: Graphical representation of area under the disease progress curve (AUDPC) in Kakamega season I and II.

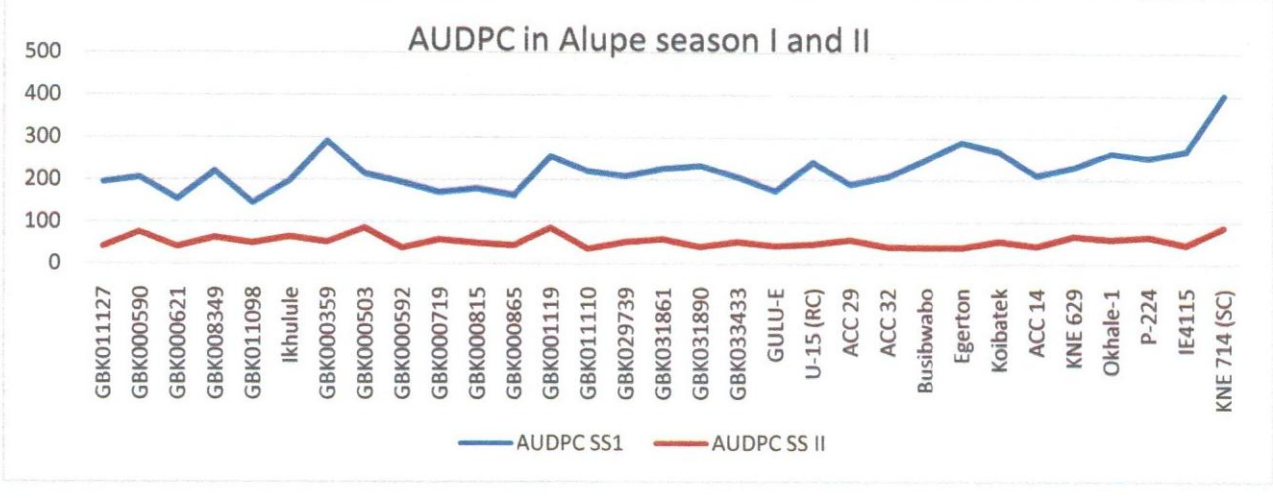

FIG 3. Graphical representation of area under the disease progress curve (AUDPC) in Alupe season I and II.

3.4.5: Genotypic variation for yield and yield traits of test finger millet varieties in Alupe and Kakamega, Kenya (2011/ 2012).

Results of combined analysis of variance (ANOVA) across seasons in each site are shown in table 3.9 and Appendix 7. Genotype, and the interactions between genotype and site (G×E), and genotype and season (G×S) (year) affected the yield and most yield components of tested finger

millet germplasm (Appendix 7 and 8). ANOVA shows a significant difference in the two sites and seasons in yield. Overall grand mean yield for all the two seasons (2011-2012) in two sites was 1406Kg ha^{-1}. Mean yields were higher in season II (2011) (1243kg ha^{-1}) compare season I (2012) (1233kg ha^{-1}) (Table 3.8 and 3.9).

In Alupe season one; yield ranged from 57.7 – 1016.7 Kg $ha^{-1}$with a mean 370 Kg ha^{-1}(Table 3.9). High yielding genotypes were Busibwabo, GBK000702, GBK033569 and U-15 with means of 1016.7, 888.9, 7772.2 and 766.7 Kg ha^{-1} respectively (Table 3.8). Blast resistant variety check U 15 had yield of 767.7 Kg ha^{-1} and susceptible check KNE 714 had 510 kg ha^{-1} (Table 3.8). Mean yield values for commercial varieties P224, IE4115, ACC29, ACC32 were 500, 717.7, 144.4 and 411.1 kg/ha respectively (Table 3.8and Appendix 7). In season two the highest yielding genotypes were ACC14, GBK008294, Okhale and GBK029869 (4077.8, 3844.4, 3816.7 and 3777.7 Kg ha^{-1} respectively) (Table 3.8 and Appendix 7). Resistant check U 15 had 2044.4 Kg ha^{-1} and susceptible check KNE 741 had 1405.6 kg ha^{-1} (Table 3.8).

Combined analysis over the two seasons in Alupe showed that the lowest yielding genotypes were GBK027169, GBK029713, GBK000119, GBK000364 and GBK043185 (617, 644, 653, 750 and 756 Kg ha^{-1}, respectively) (Appendix 7). Medium yielding genotypes were, Ikhulule, U15, GBK000608, GBK033576 and GBK000638 (1414, 1406, 1400, 1394 and 1375 Kg ha^{-1} respectively (Appendix 7). Average yields in Alupe were greatest in season two (2422Kg ha^{-1}) compared to season one (369.3 kg ha^{-1}) (Table 3.8 and figure 4). From results high yieldinggenotypes were Busibwabo, GBK000702, GBK033569, U15, GBK029875 and 1E4115 while the least yielding were GBK027076,GBK036839 and GBK000638 (Table 3.8 and Appendix 8).

In Kakamega season one yield ranged from 223 -1316.7 Kg ha^{-1} with a mean 634 Kg ha^{-1}(Table 3.11 and Appendix 8).High yielding genotypes were Busibwabo, GBK029875, GBK000702 and GBK000845with means of 1316.7, 1294.4, 1200and 1172.2 kg ha^{-1} respectively (Table 3.9 and figure 5). U 15 had 866.7 Kg ha^{-1} and susceptible check KNE 714 had 811.1 kg ha^{-1} (Table 3.9). Mean yield values for commercial varieties P224, IE4115, ACC29, ACC32 were 905.6, 67.2, 227.8and 605.6kg/ha respectively) (Table 3.9). Local genotypes Ikhulule and Egerton had mean of 216.7 and 716.7 while Okhale had 994.4Kg ha^{-1} respectively (Table 3.11).

TABLE 3.8: Yield performance and yield components traits of selected genotypes in Alupe 2011/2012

Variety	SS I (Kg/ha)	SSN II (Kg/ha)	HT (Cm)	DAF (days)	DM (days)	TLRS	% LDGN
ACC 14	351.1	4077.8	68.5	78.0	105.2	2.8	1.8
GBK029869	622.2	3777.8	72.3	75.2	101.5	3.3	3.2
GBK029875	728.8	3583.3	72.5	72.5	101.0	3.2	3.6
Okhale-1	483.3	3816.7	65.3	73.8	102.8	3.2	22.0
GBK008294	167.7	3844.4	67.3	71.8	101.7	2.6	4.0
Busibwabo	1017.7	2983.3	76.0	71.8	99.8	4.0	29
P-224	500.0	3472.2	63.0	72.3	100.8	3.0	5.6
GBK027155	383.3	3444.4	76.5	71.6	99.7	3.3	5.5
IE4115	717.7	3083.3	62.6	69.8	98.2	2.8	3.2
GBK000414	333.3	3455.6	69.6	73.5	101.3	3.5	5.8
GBK033569	772.2	2894.4	71.3	69.8	99.8	3.8	5.2
GBK000882	289.9	3372.2	66.8	70.0	100.8	6.6	4.2
GBK011059	294.4	3261.1	69.3	77.2	101.3	3.3	14.5
GULU-E	633.3	2905.6	66.0	71.8	102.3	2.6	2.5
GBK000702	889.9	2555.6	66.0	68.2	99.5	3.5	4.2
GBK043069	217.7	3194.4	60.0	78.0	101.3	2.7	1.3
GBK000766	211.1	3166.7	64.5	77.5	99.8	3.2	5.2
GBK011110	156.6	3216.7	68.2	80.0	105.2	2.5	4.8
GBK043065	517.7	3044.4	75.3	71.2	100.3	3.7	44.8
GBKO43161	611.1	1883.3	75.2	71.8	100.2	3.7	6.5
GBK033605	283.3	2850.0	66.8	79.0	101.0	2.6	1.2
GBK029850	228.8	3094.4	68.3	77.5	102.8	3.2	2.0
GBK029837	267.7	2994.4	66.6	77.5	103.5	3.5	3.3
Egerton	561.1	2650.0	77.1	73.2	101.5	3.8	46.8
U-15(RC)	767.7	2044.4	64.8	65.8	95.2	2.3	3.7
KNE 714(SC)	510	1405.6	57.8	58.8	88.7	4.7	3.5
RANGE	57.7-1016.7	844-4078	44-85.17	57.7-90.2	88.7-113.8	2.1-7.1	0.7-49.3
Mean	370	2422	65.7	73.42	100.8	3.33	6.61
SE	18.59	82.66	11.2	5.9	4.8	35.2	94.5
CV	25.2	34.1	7.355	4.33	7.794	1.18	6.238
LSD	29.9	91.03	8.34	4.92	5.44	1.33	7.08
Variety	***	***	***	***	***	***	***
Season	***	***	***	***	***	***	***
Sea*var	***	***	***	***	***	***	***

KEY: **SSN1**=Season I, **SSN11**=Season II, **PHT**=Plant height, **DF**= Days to flowering, **DM**=Days to maturity, **TLRS**=No of tillers, **LDGN**= Lodging

TABLE 3.9: Yield performance and yield components traits of selected genotypes in Kakamega 2011/2012

Variety	SSN I (kg/ha)	SSN II (kg/ha)	PHT (cm)	DF (days)	DM (days)	TLRS	% LDGN
ACC 14	911.1	1822.2	83.6	84.8	115.7	4.0	5.3
GBK029869	777.7	264.4	64.5	85.7	116.3	4.0	7.3
GBK029875	1294.4	2277.8	72.8	81.0	111.8	4.6	15.6
Okhale-1	994.4	2772.2	70.2	81.2	110.0	4.0	12.5
GBK008294	655.7	2644.0	61.0	79.5	110.2	3.8	12.0
Busibwabo	1316.7	2800.0	76.3	80.6	111.2	5.5	45.0
P-224	905.6	2566.7	64.0	80.5	110.5	4.1	18.6
GBK027155	755.6	2861.1	81.8	81.3	111.5	4.6	43.5
IE4115	672.0	1933.0	57.2	82.8	113.2	4.2	3.5
GBK000414	300.0	2217.0	68.2	85.0	116.0	5.3	17.7
GBK033569	1166.7	3977.8	71.2	80.6	111.2	5.8	33.67
GBK000882	1072.2	2116.7	66.0	70.0	100.8	6.0	38.6
GBK011059	377.7	111.7	59.8	85.2	114.5	3.5	6.2
GULU-E	761.1	2394.4	62.0	80.0	111.5	3.8	5.3
GBK000702	1200.0	3205.6	69.2	77.3	107.2	5.8	15.5
GBK043069	405.7	1861.0	64.7	94.8	123.8	3.3	5.7
GBK000766	222.3	136.1	59.8	92.8	123.8	4.2	2.2
GBK011110	1005.7	1683.0	69.3	71.7	102.8	5.8	42.0
GBK043065	494.7	2472.0	74.5	80.8	111.0	4.3	43.8
GBKO43161	588.7	2567.0	69.8	80.2	111.0	4.3	32.7
GBK033605	166.7	1561.0	65.8	84.8	117.3	4.5	2.5
GBK029850	127.7	1356.0	60.2	96.8	124.3	3.3	3.2
GBK029837	277.7	1611.0	63.5	86.3	117.5	2.8	2.5
Egerton	716.7	3150.0	80.3	84.3	116.5	5.0	43.3
GBK033433	566.7	1639.0	70.8	88.2	118.8	3.7	2.8
GBK000458	394.3	1811.0	54.3	81.7	114.0	5.2	2.2
U-15(RC)	866.7	2472.2	60.2	77.0	107.7	4.5	11.6
KNE 741(SC)	811.1	2550.0	65.2	74.0	112.0	8.5	35.0
RANGE	223-1316.7	594-3978	47.1-90.5	68-104	100.8-131.7	2.7-8.5	1.8-63.3
Mean	634	2201	67.12	82.25	112.82	4.9	18.08
SE	26.76	55.29	5.93	4.85	4.187	3.62	12.802
CV	42.2	25.1	8.8	5.9	3.7	32.2	70.8
LSD	43.09	89.03	6.73	5.50	4.75	1.6	14.53
Variety	***	***	***	***	***	***	***
Season	***	***	***	Ns	***	***	***
Sea*var	***	***	***	***	***	***	***

KEY: **SSN**1=Season I, **SSN1**1=Season II, **PHT**=Plant height, **DF**= Days to flowering, **DM**=Days to maturity, **TLRS**=No of tillers, **LDGN**= Lodging

In Kakamega season two yields ranged from 594 – 3978 Kg /ha with a mean of 2201Kg ha^{-1} (Table 3.9).Highest yielding genotypes were GBK033569, GBK000638, GBK011044 and GBK000513 with a mean of 3977.8, 3933.3, 3311.1 and 3255.6 Kg ha^{-1} respectively. Commercial varieties P224, IE4115, ACC29, ACC32 had means of 2566.7, 193.3, 1561.1 and 2127.8 kg/ha respectively (Table 3.9and Appendix 8). From results high yielding genotypes were Busibwabo, GBK0729875, GBK000702, GBK000845 and GBK000463 while the least yielding genotypes wereGBK011127, GBK039367 and GBK000678 (Table 3.9).

On average over all growing seasons, the highest mean yields were realised in Kakamega (1417kg ha^{-1}) compared with Alupe (1394Kg ha^{-1}) (Table 3.8 &3.9). Combined analysis of the two growing seasons (years) in the two sites showed that genotypes GBK033569, Busibwabo and Okhale had the greatest grain yields (2202.8, 2029.2 and 2016Kg ha^{-1}, respectively)(Table 3.8 and 3.9). The lowest yielding genotypes were GBK001119, GBK029713, GBK011127 and GBK000678 (652.8, 751,890.3 and 898.6 Kg ha^{-1}, respectively) (Table 3.8). Blast resistant genotypes (U-15 and susceptible check yielded more in Kakamega as compared to Alupe (Table 3.8 and 3.9). However, genotypes P224 and ACC14 had lowest grain yield in Kakamega than in Alupe (Table 3.8 and 3.9). Overall genotypes Busibwabo, GBK000702, GBK029875, GBK033569, GBK033548 and GBK000493 had high yield ranging between 1166.7 to 844.4 kg ha^{-1}. These genotypes performed well above the commercial varieties (Table3.8 and 3.9). Genotypes GBK001119, GBK000503, KNE741, GBK033548, GBK033464 and GBK000493 matured early below 100 days and were high yielding apart from GBK001119 and GBK000503. They were however associated with very few number of tillers.

Yield components; number of tillers, plant height, days to flowering, lodging and physiological maturity varied across the test cultivars. Days to flowering ranged from 54 to 97 days in Alupe with a mean of 74 days while physiological maturity ranged from 88 to 113 days with an average of 100 days in Alupe. In Kakamega, flowering ranged from 68 to 104 days with an average of 82.3 days while physiological maturity ranged from 100 to 131 days with an average of 112.8 days. This shows that varieties take shorter time to flower and mature in Alupe than in Kakamega. This could be attributed to climate and type of soil in Alupe which varies from that of Kakamega. Overall Susceptible check KNE714 was the earliest to flower taking 58 days to flower and 88 days to mature compare to ACC14 that takes 78 days to flower and 105 days to mature (Table 3.8 and 3.9).This variety could be selected for earliness. The variety is

also among the shortest varieties with a mean height of 57.8cm (Table 3.8). Genotypes KNE714, GBK000904, and GBK033592 matured early below 92 days but had lower yield. Genotypes took between 95 to 119 days to mature with genotypes GBK000503, GBK000904 and GBK001119 taking 96, 97 and 98 days respectively while GBK039367, GBK000592 and GBK000815 took 199,119 and 117 days respectively (Table 3.8 and 3.9). Other yield components like Plant height ranged from 38.67cm to 92 cm with average height of 65.7cm in Alupe while in Kakamega ranged from 47.17cm to 90.5cm with average of 67.09cm. High number of tillers was observed in Kakamega as compared to Alupe (Table 3.8 and 3.9). High lodging was also observed in Kakamega (7.27%) compared Alupe (3.9%) (Tables 3.8 and 3.9)

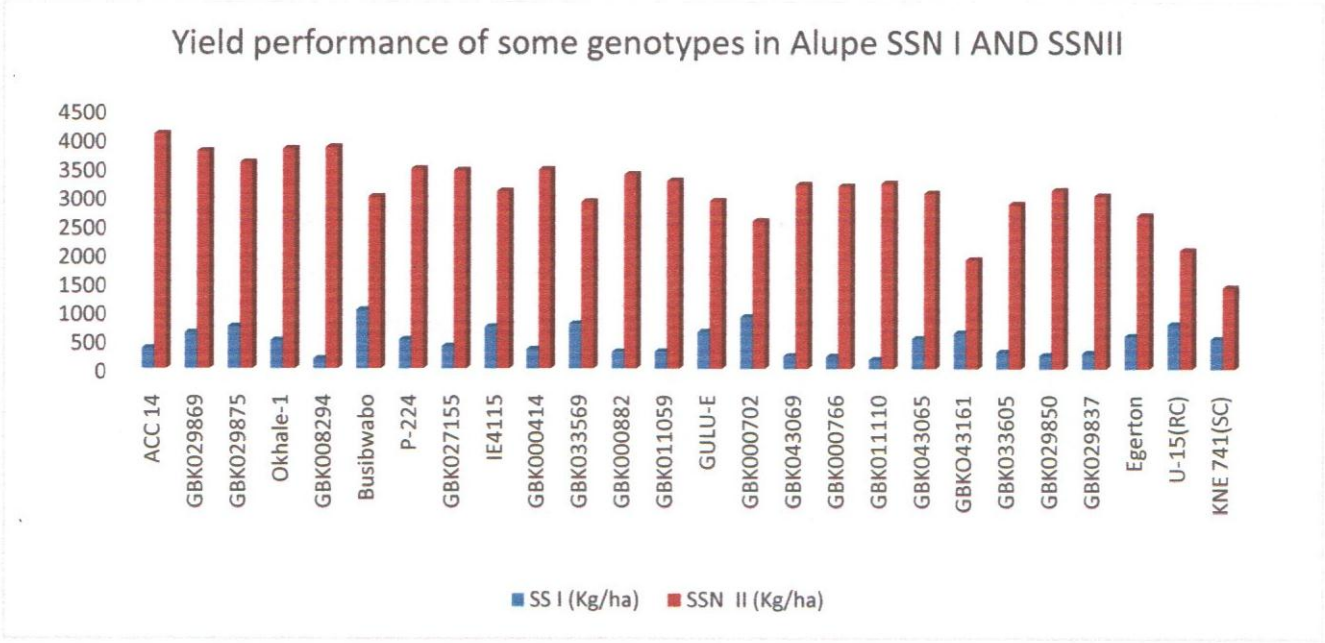

FIG 4: Yield performance for selected finger millet genotypes in Alupe season I and II

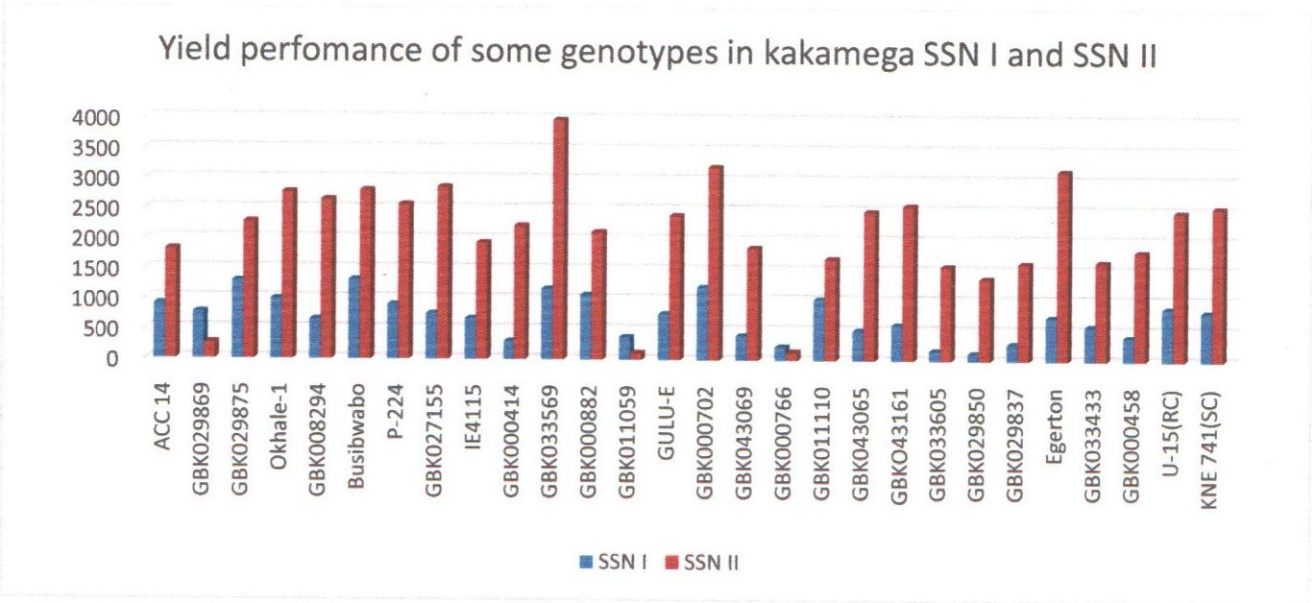

FIG 5: Yield performance for selected finger millet genotypes in Kakamega season I and II.

3.4.6: Pearson correlation between yield, disease scores and yield components

Leaf, neck and finger blast severity was negatively correlated with plant height ($r = -0.41, -0.09$ and/or 0.02 and days to flowering ($r = -0.26, -0.55$ and/or -0.56 (Table 3.11). Leaf, neck and finger blast severity was also negatively correlated with physiological maturity ($r = -0.47, -0.47$ and/or 0.51 (Table 3.11). A significant moderate correlation was observed between leaf blast, neck blast and finger blast with yield ($r = -0.45, -0.07$ and 0.04 whereas, neck and finger blast ratings had a high correlation ($r = 0.87$, $P<0.001$) (Table 3.11). However, there was also a positive correlation between plant height and lodging of 0.42 and no correlation between foliar severity and neck severity.

TABLE 3.11: Correlation coefficient (r) for yield and disease component in Alupe and Kakamega 2011/2012

Trait	DM	Folia inc	Foliar sev	Neck inc	Neck sev	Plant HT	finger inc	finger sev	YLD	D50%	LDGN	TLRS
DM												
F inc	0.058											
F sev	-0.47	0.75										
N inc	-0.41	0	-0.2									
N sev	-0.47	0.15	0.01	0.75								
PHT	0.03	-0.32	-0.41	0.25	-0.09							
FIN inc	-0.44	0.00	-0.17	0.82	0.69	0.28						
FIN sev	-0.51	0.13	0	0.76	0.87	0.02	0.83					
YLD	-0.02	-0.37	-0.45	0.23	-0.07	0.74	0.28	0.04				
D50%	0.84	-0.28	-0.26	0.53	-0.55	-0.05	0.53	-0.56	-0.13			
LDGN	0.06	-0.03	-0.07	-0.06	-0.2	0.42	-0.02	-0.15	0.35	0.12		
TRS	0.1	-0.03	-0.01	-0.14	-0.15	0.1	-0.1	-0.11	0.08	0.05	0.19	

KEY: **DM**=Days to maturity; **F Inc** =foliar incidence; F **Sev**= foliar severity; **N Inc**=neck incidence; **N Sev**=neck severity; **PHT**=Plant; **LDGN**%= 50% lodging; **TLRS**=no of tillers, **FIN Inc**=finger incidence; FIN **sev**=finger severity, **YLD**= Grain yields kg ha-1

3.5 Discussion

3.5.1 Genotypic response to disease infection in the field both sites

The findings of study shows consistent trend in response to disease was observed in some genotypes. Finger millet was grouped into five groups in relation to their reaction to the disease. This shows there is wide diversity amongst the test genotypes evaluated. Finger and neck blast causes significant yield losses to susceptible genotypes compared to foliar blast. The results of the experiment suggested that Pyricularia severity depends mainly on climatic conditions and resistance level of studied varieties. Humidity played an important role in all stages of the infection of the pathogen. Resistant genotypes were more stable across environments then susceptible genotypes.

Combined analysis showed that none of finger millet genotypes could exhibit complete resistance to the three types of blast or evade the blast infestation completely in both sites and two seasons. Genotype by environment interaction occurs when different genotypes respond differently to different environments. This study thus evaluated a hundred finger millet genotypes in two different environments over two seasons to establish sources of blast resistance. The significant effect of site and season occurred in leaf, neck and finger blast infection levels could be due to variable weather conditions in the two sites. Such differences in weather conditions influencing disease level is a known fact (Koutroubas *et al.*, 2009). Environmental conditions, especially relative humidity and temperature could strongly affect the sporulation, release and germination of blast conidia (Ou 1985). It was observed that blast incidence and severity was higher in Alupe than in Kakamega in both seasons. This could be attributed to environmental conditions especially high temperature and humidity in Alupe that favors development of blast. For instance, susceptibility to finger blast disease for variety U-15 was 25.8% in Alupe whereas in Kakamega was 7.8% while GULU- E had foliar severity of 10.1% in Alupe while in Kakamega was 6.3%.Disease incidence and severity were significantly low in season one compared season two in all sites. This could be attributed to low precipitation, low humidity and high temperature which do not encourage blast development.

The negative correlation between foliar severity and yield was expected because foliar blast is known to cause significant yield loses (Prabhu *et al.*, 2003). Its negative correlation with plant height could be explained in that tall and late maturing genotypes might escape infection (Nagaraja *et al.*, 2010).Foliar blast negative relationship with D50, plant height, PM, and yield would be expected as foliar blast affects plant leaves that contribute to growth leading to reduced plant performance.

Low yield was observed to genotypes that were susceptible to neck blast compared resistant varieties. This could be attributed to lesions coalescing into larger lesions that lead to leaf neck deformation thus poor transport system leading to poor growth due to blockage of vascular bundles leading to poor yield. A highly significant positive correlation ($r = 0.87$) for neck and finger severity suggests that the significant year effects didn't cause much impact on the disease severity reaction of neck and fingers, hence neck and finger blast are more destructive as reported earlier by Nagaraja *et al.*, 2010. The results also revealed that the virulence of the

disease in finger millet was affected by days to maturity of the crop. Early maturing genotypes were more susceptible as compared to late maturing varieties as indicated by negative correlation between foliar severity with plant height and days to maturity. Tall and late maturing genotypes might escape infection. The finding confirms the earlier report of Nagaraja *et al.,* 2010.

Genotypes with dark colored seeds and compact heads were more resistant compared to white seeded and open headed genotypes. This finding was also in agreement with the report of Obilana, (2002) and Takan *et al.*, (2004) whose findings showed that dark and compact head are more resistant to blast than white and open headed varieties in Busia, Teso and Kisii districts in western Kenya.

Foliar blast occurred in a majority of germplasm at the seedling stage, which did not correlate well with crop growth stages and maturity of the plants, probably because of the buildup of adult plant resistance. Significant moderate correlations between leaf blast with neck and, finger blast suggests that a high level of leaf blast severity may not result in severe neck or finger blast during the later stages of plant development. Poor correlation has been observed for leaf blast with neck blast ($r = 0.04$) and finger blast ($r = 0.27$) infection in finger millet (Somashekhara *et al.,* 1991). It has been reported that seedlings of finger millet are more susceptible to leaf blast than mature plant (Rachie and Peters 1977). However, no relationship is known between the intensity of seedling infection and that of later neck and finger infection. Rather prevailing weather conditions at a particular stage of crop development determine the intensity of blast infection (Esele 2002). Contrasting responses between the vegetative stage and reproductive stage often occur indicating differential gene expression for resistance to leaf, neck and/or finger blast infection. This shows that resistance to finger blast may be in some finger millet genotypes independent from resistance to leaf blast. The results agree with earlier work of Somashekhara *et al.*, 1991. Chaudhary *et al.*, (2005) also reported similar results in rice. In contrast, finger blast severity did not correlate well with agronomic parameters measured probably because of the build-up of adult plant resistance. The negative correlation between plant height and foliar severity, neck severity and finger severity indicates that tall varieties might escape blast infection due to less favorable microclimatic conditions (Thakur *et al.*, 2009).

Information on character correlations and character contribution to yield are pertinent to an Efficient breeding scheme (Toker and Cagirgan, 2004). The positive correlations between plant height, lodging, and yield suggest taller genotypes tend to mature late, yield more and more lodging. The positive correlation between plant height and yield has also been observed in rice (Araujo *et al.,* 2000). The positive correlation between lodging and plant height is common (Crook and Ennos, 1994). Except for lateness and lodging, taller genotypes would be the choice in a breeding program. The negative correlation between plant height and the foliar blast severity implies the stresses reduce with plant height. From the weather data collected during the two growing season it shows that Alupe was warmer and humid compare to Kakamega during both the growing seasons, hence the reason for more disease development in this site. AUDPC is a good indicator for adult plant resistance under field conditions (Wang *et al.*, 2005). In this study genotypes which had lowest AUDPC and terminal severity values were recorded and their terminal severities were also small. The mixture effect of *P. grisea* appears variable and environmentally influenced.

The relationship between finger millet plant height and days to maturity indicates that management of millet genotypes should be optimized to reduce the *Pyricularia severity*. Thus, the greater plant height was strongly associated with lower AUDPC values reducing the chance of contact between pathogen and host. Shortest genotypes showed higher necrosis percentage and AUDPC values. There was also a correspondence between genotypes susceptibility and AUDPC showing that the most susceptible millet genotypes recorded high AUDPC values. In the above results it can be easily inferred that the genotypes GBK011127, GBK027076, GBK000865, GBK033520, GBK0333605, GBK000621, GBK029869, GBK000592, GBK033513 and GBK029850 have got the general resistance for all the three different types of blast diseases and can be used as resistance sources. In light of this, these genotypes could be selected and promoted as important source of resistance. On the other hand, most of the genotypes such as GBK033592, GBK036767, GBK027169, GBK000503 and GBK033418 were susceptible to blast as their AUDPC values were relatively high.GBK036767 was the most susceptible to blast infection as depicted by the high AUDPC and terminal severity value and low yielding at the same time which could be due presence of high disease pressure. The Area under the Disease Progress Curve (AUDPC) can be an efficient instrument to evaluate the epidemic development of foliar blast pathogen considering each genotype susceptibility and

specific architecture. Even though the yield obtained from some of test genotypes were high, their current susceptibility to blast is a warning to the potential risk associated with the continuous production of these varieties. Thus a breeding program should be devised to cross the high yielding susceptible varieties with disease resistant genotypes such as GBK00865 and GBK000592 having low AUDPC and terminal severity. A very high plant damage rating was observed at flowering and maturity stage. This finding was also in agreement with the report of Nagaraja *et al.*, (2010) who claimed that the neck and finger blast are more destructive than foliar blast.

3.5.2 Genotypic performance of test genotypes in both sites

The findings of study showed potential finger millet germplasm with high productivity and low blast reaction on fields in Alupe and Kakamega. Significant genotypic variability ($P<0.01$) for yield and yield component traits were observed across the trials for grain yield, plant height, number of tillers, days to flowering, days to maturity and plant height. This showed there was a wide diversity amongst the test genotypes evaluated. Combined results for grain yields across the sites showed that genotypes GBK000702, GBK033569, GBK033548, GBK029875, ACC14 and Busibwabo performed well in overall. These genotypes yielded more than the released Kenyan commercial checks genotypes U-15 and P224. In contrast GBK029713 and GBK036767 yielded lowest in both sites. Busibwabo, U15, Ikhulule have shown some resistance to blast than variety P224. They also have high yield returns than P224. The local genotype Ikhulule if well managed has good potential especially good for blast resistance but have low yield returns.

A higher yield was observed during the season two (long rains) as compared to short rains. This could have been due to sufficient grain filling due to availability of moisture during the long rains while inadequate moisture during the short rains could have contributed to inadequate grain filling due to water stress. It was also evident that although grain yields were low in season one, the performance of the genotypes was relatively consistent. Highly significant genotypic x environmental interaction was observed for all the traits measured across the environments showing the importance of carrying out multi environmental trials across the sites and seasons. Differences in performance across seasons indicated that different genotypes are adapted differently across seasons and it's therefore important to select suitable

variety for individual season. Genotypes Busibwabo, Okhale, GBK000702, GBK079869 and GBK036839 were ranked best because they gave good yield, resisted lodging and were resistant to blast disease. Although genotypes GBK033569 was highest in yield, its susceptibility is high. Varieties ACC14, GBK029869, GBK029875, Okhale, GBK008294, Busibwabo, P224 and GBK027155 were suitable for Alupe whereas GBK033569, GBK000638, GBK000702, GBK000513, GBK029747, Busibwabo and GBK011044 were suitable for Kakamega.

Plant height varied from 38 to 92 cm. Although GBK043161 was the tallest, it had a relatively low lodging score of 2 indicating that it has a strong stem. Susceptible check KNE714 was the earliest to flower taking 58 days to flower and 88 days to mature compared to ACC14 that takes 78 days to flower and 105 days to mature. These genotypes could be selected for earliness and can also be useful as drought escape therefore is suited to drought environmental conditions. Among all genotypes, GBK033592 had significantly higher tillers than other entries, while accession GBK033474 had significantly lower tillers than the other entries.

Days to flowering and physiological maturity were positively correlated, but were not correlated to yield, contrary to Bedis *et al.,* (2006) report. The positive correlation between DF and PM was high as expected because the two are maturity traits. This is in agreement with the findings of Bedis *et al.*, (2006); John (2006). The DF characteristic was negatively correlated to neck severity, finger severity and foliar severity. These correlations suggest that late flowering genotypes tended to resist blast, but not for yield, which was not significantly correlated to D50. Bezaweletaw *et al.*, (2006) found finger millet grain yield per plant to be significantly negatively correlated to days to heading and days to physiological maturity. However, through path coefficient analysis, they found days to heading to have high positive direct effect on grain yield per plant and days to maturity had very high negative direct effect.

Positive correlation between Plant height and lodging suggesting tall germplasm had high percentage lodging compared to short genotypes. In contrast ACC32 is short but had relatively high lodging index indicating that it has a weak stem. Among the resistant genotypes, Busibwabo had desirable agronomic traits such as early flowering, medium plant height and semi-compact to compact inflorescence. These would be desirable sources of resistance for a finger millet breeding program.

High significant genotypic × environment interaction was observed for all traits measured across the environments showing importance of carrying out multi location trials across site and different ecological zones to find the best adapted genotypes for each environment. The interaction between site and season was also observed in all sites that resulted in different performance of genotypes across the seasons. These indicate that genotypes are adapted differently and it is therefore advisable to select genotypes that are suited for particular seasons.

4.0 Conclusion and recommendation

4.1 Conclusion

Results of field evaluation showed that genotypes GBK027076, GBK000865, GBK029850 and GBK000592 were tolerant to all three phases (foliar, neck and finger) of blast disease in all sites than commercial varieties U15 and P224. They also had high yield than most commercial varieties. The local genotypes Ikhulule also had above average yield than the other local genotypes (Egerton, Koibatek). Genotype GBK033513 had better tolerance than most varieties, however low yielding. Genotypes that had higher yielding during short seasons (drought tolerant) included Busibwabo, Okhale, GBK000702, GBK000882, GBK033569 and GBK029875. This could be recommended for other low rainfall areas.

4.2 Recommendations

1. Breeding work on various aspects of the crop need to be encouraged by breeders especially towards high yielding genotypes that are resistant to blast disease.
2. Resistant genotypes GBK000702, GBK000513, GBK029869, GBK029875, GULU-E, GBK000752, Busibwabo, and GBK027155 to be included in a breeding to enhance their resistance.
3. High yielding genotypes Busibwabo, Okhale, GBK000702, GBK000882, GBK033569 and GBK029875 are recommended for further multi location evaluation and possible release as commercial varieties. These promising genotypes could also be used to broaden the genetic diversity of the available finger millet germplasm since these materials have shown diverse levels of resistance. This could be achieved by introgressing the resistance into adapted but susceptible finger millet cultivars through backcross, pedigree selection, mass selection and/or bulk population breeding. This will help offset further yield losses.

CHAPTER FOUR

AVALUATION OF FIELD SELECTED GENOTYPE FOR RESISTANCE TO BLAST UNDER GREENHOUSE CONDITION

4.0 Abstract

Blast caused by *Pyricularia grisea* is an economically important and widespread disease of finger millet in east Africa. Host resistance is the most economical and effective means of combating this disease as finger millet is predominantly grown by resource-poor and marginal farmers. A total of 15 finger millet genotypes including checks were evaluated for resistance to blast at Egerton University in2014. The study was carried out with a view to evaluate the proportion of genotypes showing differential reaction to blast reaction of finger millet in controlled environmental condition. To address the problem, fifteen finger millet genotypes were evaluated for blast disease tolerance. Genotypes were selected from field experiment in KALRO Kakamega and Alupe and were artificially inoculated with blast isolates in Egerton University in CRD. These genotypes were screened to assess their blast reaction status and identify blast resistant genotypes for farmer use and as sources of resistance in breeding and varietal improvement program. Unlike the occurrence of natural leaf blast under field conditions, artificial inoculation generated some paradoxical results showing a high proportion of susceptibility in the genotypes that were resistant in the field. The number of sporulating lesions and the number of leaves with at least one sporulating lesion per plant were considered as measures for evaluation of quantitative resistance in the greenhouse assay. Genotypes Busibwabo, U15, GBK033575, GBK000752, GBK043161 and Ikhulule were promising varieties for quantitative resistance to both leaf and neck blast hence these could be promoted for cultivation in blast-prone environments. These genotypes could also be utilized as donor parents for breeding durable blast resistant varieties. The most virulent blast isolate could be used for evaluation of both qualitative and quantitative resistance to blast in early generation in the greenhouse so that workload could be cut down in future works.

4.1 Introduction

Finger millet is not only important in the diets and economy of subsistence farmers but is also increasingly demanded as processed flour and porridge by urban consumers in the semi-arid tropics of East Africa. The most serious constraints in finger millet production are those related to productivity enhancement (Oduori *et al.,* 2007). Blast caused by *Pyricularia grisea* is the most constraint to finger millet production in East Africa (Anon., 2008; Takan *et al.,* 2004). Blast affects finger millet at all stages of growth and most of the landraces and commercial varieties are highly susceptible causing yield losses of 10% to 80% in Kenya and Uganda (Holt 2000; Obilana, 2002; Takan *et al.,* 2002).Control of plant diseases has depended primarily upon the application of fungicides, despite potentially toxic effects on humans, wildlife, and the environment (Hong-Sik *et al.,* 2000).Major gaps exist in the knowledge of the pathogen interactions with the host, thus impeding effective disease control (Sreenivasaprasad *et al.,* 2006).Thus breeding for resistant is most economical method to control the disease. Neck and finger blast are the most destructive form of the disease (Pande *et al.,*1995: Takan *et al.,* 2012).The most susceptible stage for foliar blast is seedling stage, whereas for neck and finger blast is Pre-flowering stage (Nagaraja *et al.,* 2007). Growing cultivars with durable resistance is the best means of combating the blast disease in finger millet. Resistance in finger millet to *P. grisea* is often evaluated in the field under natural infection (Somashekhara *et al.,* 1991; Takan *et al.,* 2004; Mgonja *et al.,* 2007; Nagaraja *et al.,* 2007, 2010). Screening under natural infection condition may provide escapes and the true resistance may not be identified (Thakur *et al.,* 2009). The prime Objective of this study was to evaluate field selected finger millet in greenhouse by artificial inoculation in order to identify resistant varieties to blast disease that could be utilized in resistance breeding programs.

Successful management of blast through new knowledge of the host-pathogen interaction will substantially contribute to increasing finger millet production and utilization in East Africa.

4.2 Materials and methods

Fifteen finger millet resistant genotypes selected for their low blast levels and good agronomic performance were used with the aim of identifying any resistance in the field selected finger millet to *P. grisea.* The genotypes included advanced genotypes (Ikhulule, Gulu E, U15 and Busibwabo). The experiment was carried out at Egerton University green house to determine the levels of resistance since the results from greenhouse screening are much more reliable than those from field screening because the environment and initial level of infestation are more or less uniform in all plants being tested. Resistance to leaf blast in field selected finger millet germplasm along with checks was confirmed under greenhouse screening. The seedlings were raised in plastic pots (10 seedlings/pot) filled with sterilized soil in a greenhouse bay maintained at 28°C. The seedlings were inoculated at 21 day after seeding (3-4 leaf stage) with conidial suspension at a concentration of 1×10^5 spore/ml and observation made 21 days after inoculation using a hand sprayer. The conidial inoculums were applied just until the beginning of runoff from the foliage. Inoculated plants were placed in a moist chamber at 23±1°C. After inoculation for 48 hours in the moist chamber, the plastic pots containing 10 inoculated finger millet plants, were transferred to a greenhouse bay and exposed to high humidity (>90% RH) under misting for 10 days. Ten seedlings of each accession were tested in three replications (10 seedlings/pot) in a completely randomized design (CRD).Leaf blast severity was recorded for 10 days after inoculation.

4.2.1 Pathogen and Inoculums preparation

Inoculum was prepared from a single-spore representative culture of *P. grisea* from ICRISAT. Mass multiplication of fungal spores for inoculation was achieved by growing the fungus (on potato dextrose agar (PDA) medium at 26±1°C for 10 days. Spores were harvested by flooding the plates with sterilized distilled water and scrapping the growth by a spatula. The spore suspension was adjusted to desired concentration (1×10^5 spores/ml) with the help of hemocytometer. The suspension was then sieved through a double layer of muslin sleeve. The suspension was then sprayed onto the plants using a hand-sprayer until run-off. Plants were inoculated after sunset to benefit from darkness and higher humidity during the night. A conducive environment for the disease was provided in the greenhouse through frequent mist sprays of the plants and the surrounding environment with sterile water to maintain high

humidity level i.e. > 95% after inoculation. The number of sporulating lesions per seedling and the number of leaves at least with one sporulating lesion were used as the measures for partial resistance to blast. The finger millet genotypes were grouped into three categories; resistant (R), moderate resistant (MR) and susceptible (S) based on lesion types, as mentioned in experiment one.

4.2.2 Evaluation of inoculated plants for resistance to Blast disease

The inoculated plants were monitored daily for blast development and disease evaluations were done 21 days after inoculation. Plants were scored based on the severity scale of 1 to 9 as shown in the table 4.1 below.

TABLE 4.1: A quantitative severity scale for foliar blast disease on finger millet

Scores	Reaction category	Appearance of genotypes
1	Very highly resistant	Free from any damage
2	Highly resistant	Less than 10% of the leaves damaged
3	Resistant	11-20% of the leaves damaged
4	Moderately resistant	21 to 30% of the leaves damaged
5	Intermediate	31 to 40% of the leaves damaged
6	Moderately susceptible	41 to 50% of the leaves damaged
7	Susceptible	51 to 70% of the leaves damaged
8	Highly susceptible	71 to 90% of the leaves damaged
9	Very highly susceptible	>90% almost all leaves damaged

4.2.3 Data Analysis

All data were prepared for analysis of variance by Genstat. The raw data were averaged between replicates for different genotypes. The significance of average blast infection index was tested by analysis of variance (ANOVA). Least significant Deference test (L.S.D) at 5% level of significance was used to compare cultivar means using genstat discovery edition statistical package.

The model: $y_{ij} = \mu + t_{i+} \varepsilon_{ij}$ where $i = 1, 2, 3 \ldots 15$ and $j = 1, 2, 3$

y_{ij} = Area under disease in the i^{th} finger millet line and the j^{th} replication.

μ = Overall mean.

t_i= Effect due to the i^{th} finger millet line.

ε_{ij} = Random error component.

4.3 Results

The results of analysis showed significant genotypic variation for disease severity in all tested genotypes. The results obtained clearly reveals among all the genotype studied no genotype showed immune response to leaf blast and the proportions of differential reactions for leaf blast in the entire population were different. Unlike the occurrence of natural leaf blast under field condition, artificial inoculation studies generated some paradoxical results showing a high proportion of susceptibility. Lowest leaf blast severity of 13.3% was noticed in GBK000752 while the highest was GBK011098 with severity of 35% (Table 4.2 and figure 6). The first visible symptoms of the disease developed 10-15 days after inoculation on primary leaves as elongated lesions that enlarged and attained larger sizes on some genotypes. In specific genotypes like GBK011098 the lesions coalesced. Blast lesions were later induced on the other leaves with different sizes and densities on respective varieties. In some genotypes like GBK000752, lesions developed as minute lesions on leaves. However the blast levels differed. Based on disease severity genotypes were grouped into highly resistant, resistant moderately resistant, susceptible and highly susceptible using the same scale that was used in field. Out of the 15 varieties evaluated, four genotypes were resistant, eight moderately resistant and three were intermediate to the pathogen at seedling stage according to the 1-9 severity scale. Resistant genotypes included GBK000752, Busibwabo, Gulu E and GBK000513. All these genotypes were resistant and moderately resistance under field conditions

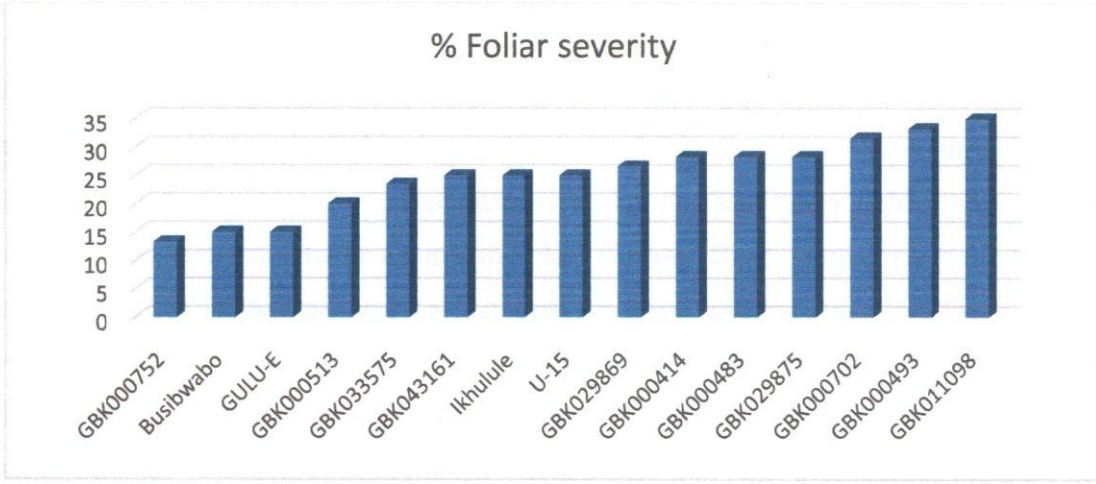

FIG 6: Finger millet foliar blast severity frequency distribution under greenhouse condition.

TABLE 4.2: Reaction of genotypes to blast disease under greenhouse conditions.

Variety	% Foliar severity	Disease reaction
GBK000752	13.3	Resistant
Busibwabo	15.0	Resistant
GULU-E	15.0	Resistant
GBK000513	20	Resistant
GBK033575	23.5	Moderate Resistant
GBK043161	25	Moderate Resistant
Ikhulule	25	Moderate Resistant
U-15	25	Moderate Resistant
GBK029869	26.6	Moderate Resistant
GBK000414	28.3	Moderate Resistant
GBK000483	28.3	Moderate Resistant
GBK029875	28.3	Moderate Resistant
GBK000702	31.6	Intermediate
GBK000493	33.3	Intermediate
GBK011098	35	Intermediate
Range	13.3-35	
Mean	24.88	

4.4 Discussion

From the results of the tested genotypes it was possible to group the fifteen genotypes into resistant to susceptible in a scale of 1-9. As compared to the field results, there was no

genotype that was highly resistant in this experiment because were exposed to high intensity of the pathogen unlike in the field where some could have escaped the inoculums. However, all resistant genotypes under this greenhouse were also resistant under field condition indicating the inherent genetic resistance against the blast disease. The findings of this study confirmed the resistance of the test genotype at the most sensitive seedling stage in a faster and cheaper way as compared to field screening. The resistant genotypes identified have potential of high yield if there is no disease outbreak later (neck blast).The findings of this study agree with earlier findings by Mgonja *et al.*, (2007) who reported that large scale screening at the seedling stage could be more economical and rapid in greenhouse than in the field. The results also showed that genotypes GBK000752, Busibwabo, Gulu-E, GBK033575 and Ikhulule (local genotypes) were tolerant to blast disease than commercial elite variety U-15. These findings also agree with those earlier reported by Takan *et al.,* (2004) where they noted that GULU-E and Ikhulule were moderately resistant in three diverse growing environments (Kisii, Busia and Teso) in two seasons. In the field experiment these genotypes also had desirable agronomic traits such as early flowering, medium plant height and compact inflorescence. They therefore could be used as desirable sources of blast resistance for finger millet breeding program in improving high yielding genotypes but susceptible varieties like P224, KNE 741 and ACC 14. The findings of this study agree with Adipala and Wandera, 2001 who reported that in Uganda Gulu-E have been used as resistant check in many pathological studies in testing for virulence and race identification since it can maintain its disease resistance reaction through test seasons and locations. Similarly, Takan *et al.,* (2004) and KiranBabu *et al.,*(2012) noted that early flowering genotypes with medium height and semi compact to compact inflorescence had better resistance to blast. These characteristics are also found in GULU-E. Upadhyaya *et al.,* (2011) found that resistant varieties were rich in nutrients such as iron, calcium and proteins which probably could contribute to increased immunity. Analysis and exploitation of these resistant genotypes would be useful step towards breeding varieties with combined traits of high grain nutrient, blast resistance and desirable agronomic traits. Despite genotypes GBK000702 being most resistant in the greenhouse study and condition, it was also among the best yielding genotypes in the field. Genotypes GBK000513 and GBK000752 were resistant in greenhouse and in the field condition which shows they have inherent resistance to blast. These genotypes also yielded highly in the field and could be selected for breeding program for

resistance and yield. GBK000493 was intermediate in the greenhouse study although it was resistant in the field trial. This is probably because they could have escaped the pathogen in the field. The findings of Nagaraja *et al.,* (2010) have reported possibility of tall and late maturing genotypes to escape the inoculum.

4.5 Conclusion

The results of this greenhouse study confirmed the findings of the field work where genotypes like GBK000752, Busibwabo, Gulu-E, GBK033575 and Ikhulule (local genotypes) that were resistant to blast disease in the field were also resistant in the greenhouse. However there is a possibility of escape as shown on genotype GBK000493. The evaluation under the greenhouse was also faster and more efficient, hence could be recommended for more accurate studies of large genotypes.

CHAPTER FIVE

CONCLUSION AND RECOMENTATIONS

5.1 Conclusion

The findings of this study showed that blast disease was more severe in Alupe than Kakamega probably due to warm, humid and wet conditions that favor proliferation of *Pyricularia grisea*. Hence Alupe is recommended of further screening of any genotypes for resistance. Greenhouse screening assisted in eliminating escape of infestation under field trials as shown by genotype GBK000493 which became susceptible under greenhouse conditions. Both field and greenhouse findings showed that variety GBK000702, GULU-E, GBK000752, Busibwabo and GBK033575 had general resistance to blast diseases and in contrast, GBK036767, GBK033592, GBK000503 and KNE741were most susceptible to the blast. The results of field evaluation showed that genotypes GBK027076, GBK000865, GBK029850 and GBK000592 were resistant to all three phases (foliar, neck and finger) of blast disease in all sites than commercial varieties U15 and P224. Similarly, greenhouse study confirmed the findings of the field work where genotypes like GBK000752, Busibwabo, Gulu-E, GBK033575 and Ikhulule (local variety) that were resistant to blast disease in the field were also tolerant in the greenhouse. Further improvement of these varieties would help in increasing resistance and improving yield and ensure food security especially in Kenya which is faced with recurrent food shortage. Further studies to generate information and knowledge on the nature of resistance in these varieties will make it easier for breeders and pathologists to exploit the genetic variability revealed. Resistant and high yielding genotypes like GULU-E, Busibwabo and GBK000752could also be used to broaden the genetic diversity of the available finger millet in Kenya since they have shown diverse levels of resistance. This could be achieved by introgression the resistance into adapted but susceptible finger millet varieties.

5.2 Recommendation

1. There is need to do more evaluation on genetic materials in gene bank because there is possibility of identifying better resistant and high yielding varieties than commercial P224.
2. Resistant genotypes GBK000702, GBK000513, GBK029869, GBK029875, GULU-E, GBK000752, Busibwabo, and GBK027155 included in a breeding to enhance their resistance

and further knowledge of the nature of resistance in these genotypes will make it easier for breeders and pathologists to exploit the genetic variability revealed.

3. High yielding genotypes like Busibwabo, Okhale, GBK000702, GBK000882, GBK033569 and GBK029875 are recommended for further multi location evaluation and further improvement of these genotypes would go a long way in combating the current global food crisis and ensure food security especially in Kenya which is faced with recurrent food shortage.

4. Genetic studies of finger millet should be carried out by breeders on plant height and days to physiological maturity to establish their usefulness in breeding for yield.

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APPENDIX

APPENDIX 1: List of evaluated finger millet germplasm in Kakamega and Alupe 2011/2012

Genotype	phenology
Gulu-E	advanced line
U-15	(commercial)
Okhale-1	advanced line
P-224	(commercial)
IE4115	(commercial)
Busibwabo	advanced line
GBK000359	medium/purple
GBK000364	tall/white
GBK000453	medium/brown
GBK000463	tall/red
GBK000487	early /white
GBK000493	tall/brown
GBK000503	tall/brown
GBK000608	tall/white
GBK000621	medium/brown
GBK000638	tall
GBK000678	fist head/red
GBK000696	early/white
GBK000719	tall
GBK000752	tall/red
GBK000766	tall/red
GBK000845	medium/brown
GBK000882	early & white
GBK000361	tall & black
GBK000409	tall and late maturing
GBK000410	early maturing & brown
GBK000414	early maturing
GBK000449	tall & brown
GBK000458	medium & brown
GBK000483	late maturing & brown
GBK000506	early maturing & brown
GBK000513	medium & brown
GBK000516	early maturing & brown

Genotype	Phenology
GBK000592	tall & brown
GBK043185	tall & purple
GBK033433	early maturing & brown
GBK033548	red
GBK033332	red
GBK033410	short & early maturing
GBK033551	early maturing & brown
GBK033575	tall & white
GBK033569	medium & brown
GBK033592	early maturing & white
GBK043258	medium
GBK043161	tall & brown
ACC#29	(commercial)
Acc#32	(commercial)
Acc#14	(commercial)
Koibatek	local
GBK000702	brown
GBK000780	tall & brown
GBK000815	early maturing
GBK000865	early maturing & brown
GBK000904	tall & red
GBK011110	brown
GBK00119	early maturing & white
GBK011059	medium & red
GBK011098	tall & brown
GBK011125	tall & red
GBK011127	tall & white
GBK011044	medium
GBK001115	Short
GBK029713	short & early maturing
GBK029819	medium & brown
GBK029850	tall & white
GBK029739	early maturing & white

Genotype	Phenology
GBK029747	late maturing & brown
GBK029837	brown
GBK029869	tall
GBK029875	early maturing
GBK027155	early maturing
GBK008294	early maturing
GBK008349	tall
GBK033418	tall & brown
GBK033464	early maturing & red
GBK033474	early maturing
GBK033513	early maturing & brown
GBK033520	tall & large head
GBK033576	medium & brown
GBK033605	medium & white
GBK043115	early maturing & red
GBK043145	short/early maturing
GBK043065	medium & brown
GBK043169	early maturing & brown
GBK043124	medium
GBK043069	tall & large head
GBK031861	short-spreader
GBK031890	early maturing & brown
GBK036839	medium height,
GBK027076	tall & fist head
GBK027169	medium height,
GBK028567	short & brown
GBK036767	medium & white
GBK039367	Short & red,
GBK040468	medium height,
KNE 714	(commercial)
KNE 629	(commercial)
Nakuru	local
Ikhulule	local

APPENDIX 2: Foliar severity scores for 100 finger millet varieties evaluated under field conditions in Kakamega and Alupe 2011 and 2012

	Kakamega				Alupe			
	season one		season two		season one		season two	
Variety	F sev	F inc	Fsev	F inc	F sev	F inc	Fsev	F-inc
GBK033576	4	2	6	1.6	21.7	2.7	2	1.3
GBK000458	4.7	2.7	11.7	2.3	26.7	3	3.7	2.3
GBK043065	5	2.3	5	2	38.3	3.4	3.3	2.7
IE4115	5.3	2.3	5	2	26.7	3	2.7	1.7
GBK011125	5.7	2.3	9.3	2	23.3	2.8	3.3	2
GBK000752	6	2.7	11.7	2.7	26.7	4	3.7	2
GBK000845	6	2.7	5	2	35	4	6.7	2
GBK033433	6	2.7	6	2	23.3	3	4.3	2.3
GBK033474	6	2.3	5	2	36.7	4.3	3.7	1.7
Okhale-1	6	2.3	9.3	2.3	26.7	2.7	3.3	1
GBK000409	6.3	2.7	8.7	2.3	30	3	5.7	1.7
GBK000487	6.3	2.7	8.7	2	30	3.7	2.7	3
GBK000696	6.3	2	11.7	2.3	26.7	2.7	2.3	2
GBK000815	6.3	2	8.7	2.3	23.3	2.3	3.7	2
GBK011098	6.3	2.3	4.3	1.7	20	2.3	2	1.3
GBK027155	6.3	1.7	11.7	2.3	30	4	2.3	2.3
GBK029837	6.3	2.7	5	1.7	25	3	2.7	1.7
GBK043258	6.3	2.7	11.7	2.7	25	3	2.3	1.4
Busibwabo	6.7	1.7	6	1.7	33.3	3.3	2	2
GBK000449	6.7	2	36.7	2.3	41.7	4	3.7	2.3
GBK000766	6.7	2.3	8.7	2	25	3	4	1.3
GBK029869	6.7	2	6	2	23.3	3.7	2.3	1
GBK031890	6.7	2.7	5	2	30	3.3	2.3	2.7
GBK033332	6.7	2.3	33.3	4	23.3	2.3	2.3	2
GBK033592	6.7	2	13.3	2.7	38.3	3.3	3.7	2.3
GBK043185	6.7	2.3	11.7	2	26.7	3	2.3	1.7
ACC 29	7	2.3	6	2.3	21.7	2.7	3.7	1
GBK000506	7	1.7	10.3	2	21.7	3	5.3	1.7
GBK011127	7	2.3	6	1.7	23.3	3	2	1.3
GBK028567	7	2.7	31.7	4	33.3	3.7	4	2.3
GBK029819	7	2	6	1.3	35	3.3	3.7	1.7
GBK029850	7	2.3	7	2	23.3	2.7	2	2
GBK029875	7	2	6	1.7	25	3.7	2	1.7
GULU-E	7	1.7	6	1.3	18.3	3	2	2
GBK000608	7.3	2	7	2	31.7	3.7	2.7	1.3

GBK011059	7.3	2	7.7	2	23.3	3.3	4	2
GBK029713	7.3	2.3	8.7	2	25	3	3.3	2.7
GBK033513	7.3	2	9.3	2	23.3	2.7	2	2
GBK043069	7.3	2.3	7	2	28.3	3.5	2.3	1.8
GBK043145	7.3	2.3	8.7	2	26.7	3.3	5	1.7
U-15**(RC)**	7.3	2.3	7	2	33.3	3.3	3.3	1.8
ACC 32	7.7	2.3	5.3	2	26.7	3	3.7	1.5
GBK000621	7.7	2.3	7	2.3	15	2.3	2	2.7
GBK000678	7.7	2.3	8.7	2	1.7	30	3.7	3.3
GBK000865	7.3	2	7	2	16.7	2.7	2	1.3
GBK008349	7.7	2.3	5	2	25	2.3	4.7	1.3
GBK027076	7.7	2.3	4.3	1.7	16.7	2.3	2	1.3
GBK033520	7.7	2.3	5	1.7	18.3	2.7	2.3	1.3
GBK033605	7.3	1.7	6	1.7	20	2.7	2	1.7
GBK036767	7.7	2.3	36.7	4	40	4	3.3	2.7
GBK036839	7.7	2	6	1.7	21.7	3	2.3	1.3
GBK039367	7.7	2	9.3	2	31.7	3.7	2.3	2.3
GBK043161	7.7	2	13.3	1.7	23.3	3	2.5	2
GBK043169	7.7	2.3	13.3	2.7	35	3.3	2	2.3
GBK000359	8	2.3	9.3	2	36.7	4	3.7	2
GBK000364	8	2.3	7	2	35	35	4.3	3.3
GBK033548	8	1.7	9.3	2	40	7	3.7	2
GBK040468	8	2.3	30	3.7	31.7	3.3	4.7	1.3
Ikhulule	8	2.3	9.3	2.3	26.7	3	5	1.7
P-224	8	2.3	7.7	2	31.7	3.3	3.3	1.3
GBK000453	8.3	2.7	25	3.7	36.7	3.7	2.7	2
GBK000483	8.3	2.3	6.7	2	30	3	4	3.3
GBK000493	8.3	2.3	11.7	2.7	36.7	3.3	3	1.3
GBK000719	8.3	2.3	11	2.7	20	2.3	2.3	2
GBK000904	8.3	2.3	30	4	35	4.7	4.7	2
GBK011044	8.7	2.3	6	2	33.3	3.3	2.3	2.3
GBK029747	8.7	2.3	7	2	21.7	3	2	2.3
GBK031861	8.7	2.3	6	2.7	30	3.7	2.7	1.3
GBK033418	8.7	3	33.3	4	38.3	4	2.3	2
GBK000361	9	3	5	1.7	35	3.3	3.7	2.3
GBK000590	9	2.3	10	2.7	28.3	3	5.3	2.3
GBK000592	9	2.7	6	1.7	21.7	3	2	1.3
GBK000638	9	2	4.3	1.7	25	2.7	3.7	1.3
GBK027169	9	2.7	53.3	4	21.7	2.7	4.7	1.7
GBK043124	9	2	9.3	2	23.3	2.3	2.3	2
GBK000414	9.3	2	8.7	2.3	25	3	3.7	1.3
GBK000882	9.3	2	26.7	3.7	43.3	3.5	2.3	2.7
GBK033551	9.3	2.3	7.7	2	41.7	3.6	2.3	3

KNE 629	9.3	2.3	6	1.7	30	3.7	5.3	1.7
KNE 714**(SC)**	9.3	2.7	10	2.3	41.7	3.7	6	2
GBK000410	9.7	2.3	20	3.3	28.3	3.3	2	1.3
GBK033575	9.7	2.7	11.7	2.3	26.7	3	8.7	2.3
Kobatek	9.7	2.3	11.7	2	35	3.3	5	1.3
ACC 14	10	2	9.3	2	25	3	3.3	1.7
GBK000463	10.0.	2.7	15	3	30	3.3	2.3	2
GBK033464	10	2	18.3	3.7	38.3	3	6	2.7
Egerton	10	3	7	2	35	4	2.3	3
GBK000503	10.7	2	36.7	4	31.7	3.3	5.7	2
GBK000516	11	2.3	6	2	31.7	3.3	3.3	2
GBK001115	11	3	23.3	3.3	31.7	4	5.7	2.3
GBK029739	11	2	7	2	26.7	3.3	2.7	1.7
GBK000513	12	3	6	1.7	28.3	2.7	4.7	1
GBK008294	12	3	11	2.3	30	3.7	2.3	2
GBK011110	12	2.3	16.7	3	28.3	3.3	2.3	1.3
GBK033410	12	2.3	36.7	3.7	33.3	3.7	7	2.7
GBK033569	12	2.7	6	1.7	40	4.7	2.3	2
GBK001119	12.3	3.3	26.7	3.7	35	4.3	5.3	1.7
GBK000702	12.3	2.3	6	1.7	23.3	2.7	4	1
GBK000780	12.3	2.7	10	2.3	31.7	3	2.3	2.2
GBK043115	13.3	2.7	35	3.7	26.7	2.7	2.7	1.3
RANGE	**5-46.7**	**1.7-3.3**	**4.3-53.3**	**1.3-5**	**8.5-23.8**	**1.7-3.7**	**2-8.7**	**1-3.7**
MEAN	**8.14**	**2.26**	**12.03**	**2.36**	**28.8**	**3.2**	**3.36**	**1.92**
SE	**1.74**	**0.46**	**3.01**	**0.57**	**5.24**	**0.72**	**0.32**	**0.48**
CV	**21.4**	**20.4**	**25.1**	**24.3**	**18.1**	**22.3**	**25.3**	**25.2**
LSD	**2.8**	**0.74**	**4.86**	**0.93**	**8.43**	**1.17**	**3.66**	**0.88**
p value	**2.81**	**0.74**	**4.86**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**

KEY: Var-variety, *, **, ***-significant at 0.05, 0.01 and 0.001 respectively **F SEV=** Neck severity, **F INC,** Neck incidence, **SC=**susceptible check**; RC=**Resistant check

APPENDIX 3: Neck severity and incidence scores for 100 finger millet varieties under field conditions in Kakamega and Alupe 2011 and 2012

	Kakamega				Alupe			
	season one		season two		season one		season two	
Variety	N sev	N inc	N sev	N inc	N sev	N inc	N sev	N inc
GBK000815	1	1.7	1.3	1	1	1.3	5	2.3
GBK029850	1	1	1.2	1.7	1	2	1.7	2.7
GBK027076	1	1	1.3	1.7	1	1	1	1
GBK000678	1.1	1.3	1.3	1.7	2	2.3	2.3	5.3
GBK029713	1.1	1.3	1.2	1.3	2.7	1.3	5	4
GBK039367	1.1	1.3	1.6	2.3	4.1	1.3	1.8	7
GBK043115	1.1	2	1.3	2	2.3	1.3	2.7	6.7
GBK000458	1.6	2.3	1.3	1.7	2.3	2.3	4.8	5.3
GBK000506	1.6	1.7	1.2	1.3	5	3.7	5	3.7
GBK000592	1.6	1	1.2	1.7	1	1	1	2.7
GBK000865	1.6	1.3	1.2	1.7	1.1	1.3	1	3.3
GBK029837	1.6	1.3	1.2	1.3	2.3	1.7	3.4	4
GBK033576	1.6	1.3	1.6	2.3	4.3	1.3	4.6	7.7
GBK043161	1.6	2.7	1.2	1.3	2.3	1.7	4.5	5
Egerton	1.6	1.3	1.2	1.3	1.1	2	3.3	3
Busibwabo	1.8	2.3	1.2	1	1	2	2.8	5.3
GBK000414	1.8	1.7	1.2	1.3	1	2	3.3	1.7
GBK000483	1.8	2.3	1.4	1.7	4.3	1.7	5	6.3
GBK000638	1.8	2.7	1.2	1.3	2.3	1.3	2	4.3
GBK011127	1.8	1.7	1.2	1.7	1	1	1	2.2
GBK029819	1.8	1.7	1.4	2	3.7	2.3	3.3	5.7
GBK029869	1.8	2.3	1.2	1	1	2	2.3	2.7
GBK033513	1.8	1.7	1.2	1.7	2.7	1.7	2.3	6
GBK033520	1.8	2	1.2	1	2.3	1	2.3	4.3
GBK033548	1.8	2.3	1.4	1.7	3.7	3.7	5	5.7
GBK036839	1.8	2	1.3	1.7	1.1	1	1	3.3
GBK043069	1.8	1.3	1.1	1.3	1	1.7	1.8	2.7
GBK043185	1.8	1.7	1.9	2.7	5	1.3	5	6.3
ACC 14	2	1.7	1.2	1	4	1.3	3.6	4.7
ACC 29	2	1.7	1.2	1.3	3.3	1.7	4.7	4
GBK000513	2	1.7	1.2	1.3	1.8	2.3	5	3.3
GBK000780	2	2.7	1.4	1	1.1	2.3	3.6	4.3
GBK000845	2	2	1.3	1.7	4.7	4.3	5	7
GBK008294	2	1.7	1.4	1.7	1.7	2.7	4.6	3.7
GBK011059	2	2	1.3	2	2.3	2.7	2.3	5.3

GBK033433	2	1.3	1.2	1	1	1.7	1.1	2.3
GBK033605	2	1.7	1.2	1	1	2	1.1	2
GBK043169	2	2.3	1.6	2.3	3.7	2.7	1.8	6.3
Ikhulule	2	1.7	1.3	1.7	1.1	1.7	2.8	2.7
Okhale	2	2	1.3	1.7	1.8	1.7	2.3	4.3
P-224	2	1.7	1.2	1	1	2	5	3.7
ACC 32	2.1	2	1.2	1.3	1.3	2.3	5	3.7
GBK000361	2.1	1.7	1.6	2.3	1.7	1.7	5	3.7
GBK000493	2.1	2.7	1.3	2.3	3.7	3.3	3.7	6.3
GBK000752	2.1	2.3	1.2	1.3	2	2.7	2.7	4
GBK000766	2.1	1.7	1.4	2	2.1	1.3	4.7	4
GBK011125	2.1	2	1.4	1.7	2.3	1.7	1.1	5
IE4115	2.1	2.3	1.2	1.7	2.5	2.3	4.7	4.7
KNE 629	2.1	2	1.2	1.3	1.6	2.3	5	3
GBK000359	2.3	2	1.4	2	2.3	2.7	5	4.3
GBK000364	2.3	2.3	1.4	5.3	3.7	2.3	5	4.7
GBK000449	2.3	2.7	1.6	2.3	3.7	3.3	4.6	4
GBK000516	2.3	2.3	1.3	2	4.3	2.3	4	5.3
GBK011044	2.3	2.3	1.3	1.3	5	1	5	6
GBK029739	2.3	2	1.2	1.3	1.6	2	1.7	4
GBK031890	2.3	2.3	1.3	1.3	1.1	2	3.7	4.3
GBK043065	2.3	2.3	1.2	1.3	1.1	1.7	1.1	3.3
GBK043124	2.3	2.3	1.8	2.3	2	2.3	3.3	4.3
GBK000409	2.5	2.3	1.6	2.3	4	2.7	5	5.7
GBK000453	2.5	2.7	1.6	2.3	1.8	2.3	4	4.7
GBK000487	2.5	2.3	1.2	1.3	4	2.3	5	6
GBK000696	2.5	2.3	1.3	2	1	1.7	1.1	3.3
GBK000702	2.5	2.7	1.5	2.3	3.3	2.3	4.8	4.7
GBK008349	2.5	2	1.6	2.3	1.1	1.3	1	3.7
GBK027155	2.5	2	1.4	1.7	2.1	2.3	5	5.3
GBK029747	2.5	2.7	1.6	2.3	1	1.3	2.3	2.7
GBK029875	2.5	3	1.2	1.7	1.3	2.3	3	4.3
GBK031861	2.5	1.3	1.2	1.7	2.7	2.3	5	4.3
GBK033332	2.5	2.7	1.2	2.3	2	1	1.1	4.7
GBK033474	2.5	2.7	1.3	1.7	4	3.7	5	4
GBK033551	2.5	2.3	1.3	1.7	4.7	2.7	5	6.7
GBK000590	2.7	2.3	1.6	2.3	4.7	1.7	5	7.3
GBK000621	2.7	2.7	1.3	2	1.8	1.3	1.6	4.3
GBK033418	2.7	2.7	3.8	3.7	5	4	5	4.3
GBK033464	2.7	3	5	2	2.3	2.7	4.2	4.3
GBK033569	2.7	3.3	1.4	1.7	3.5	2.7	3.7	5

GBK033575	2.7	2.3	1.2	1.3	1.6	2	5	3.3
KNE 714**(SC)**	2.7	3.3	2.7	2.7	3.1	3	5	5.2
Koibatek	2.7	2.7	1.6	2.3	2.7	2.7	3	5.7
U-15**(RC)**	2.7	2.3	1.2	1	1.1	2.3	3.5	3.7
GBK001115	2.8	2.7	3.6	4	2.3	2.7	4.7	4.3
GBK011098	2.8	2.7	1.2	1.3	2.5	2.7	5	5.3
GBK028567	2.8	2.3	2	2.3	2.3	2	5	5.3
GBK036767	2.8	3	4.3	4.3	5	2.3	5	8.3
GBK043145	2.8	2.7	1.4	1.6	2.3	2.3	4	4.3
GBK000608	3	2	1.3	2	2.7	2.3	40	3.7
GBK000719	3	2.3	1.3	1.7	5	1	3.6	8
GBK033410	3	2.3	1.6	2	4.3	3.7	5	5.3
GBK040468	3.1	2.7	1.6	2.3	1	2	3.7	1.7
GBK043258	3.1	3.3	1.6	2.3	1.8	1.7	2.3	5
GULU-E	3.1	2.3	1.2	1.7	1.6	1.7	4.7	2.7
GBK000119	3.3	3.3	2.1	3.3	5	4.3	5	6.3
GBK000463	3.3	3	1.2	1	3.7	3.3	4.5	5.2
GBK000904	3.3	2.7	3.3	4	4.3	4	5	6.3
GBK011110	3.3	3.3	5	5	2	1.7	2.3	3.5
GBK000410	3.7	2.7	1.6	2.3	2	2.3	3.7	5.3
GBK000882	3.8	3.7	3.7	4.3	3.7	2.3	1.1	7
GBK027169	4	2.7	5	6	3.5	2.7	5	4.7
GBK000503	4.1	3.3	3.3	3.3	3.7	3.7	5	5.3
GBK033592	4.6	3.7	3.7	4.3	4.7	2.3	5	6.7
RANGE	1-4.6	1-3.7	1-5	1.-6.1	1-5	1-7-3.7	1-5	1-3.7
MEAN	2.3	2.22	1.7	2	2.5	0.58	4.4	4.75
SE	4.77	0.45	2.27	0.5496	5.075	26.8	7.22	0.98
CV	20.6	20.7	29	27.4	19.6	0.935	17.8	20.7
LSD	1.03	0.73	0.66	0.88	0.67	0.9	0.45	0.52

KEY: Var-variety, *, **, ***-significant at 0.05, 0.01 and 0.001 respectively **NECK SEV=** Neck severity, **NECK INC,** Neck incidence, **SC**=susceptible check; **RC**=Resistant check.

APPENDIX 4: Finger severity scores for 100 finger millet varieties under field conditions in Kakamega and Alupe 2011 and 2012

	Kakamega				Alupe			
	season one		season two		season one		season two	
Variety	P sev	P inc	P sev	P inc	Psev	P inc	P sev	P inc
GBK039367	5	1.3	18.3	2.7	40	2.3	18.3	6.3
GBK000506	6	1	4	2	18.3	1.7	46.7	3.7
GBK000592	6	1	3.3	1.7	10	2	8.3	2.4
GBK000678	6	1.3	3.7	1.3	20	2	26.7	3
GBK000815	6	1.7	3.3	1.3	10	1.7	33.3	2.7
GBK000865	6	1	2	1	11.7	2	8.3	2.7
GBK011125	6	1	2.3	1	23.3	1.7	11.7	4.3
GBK033513	6	1.3	2	1	26.7	2.3	11.7	4.7
GBK043145	6	1	4	2.3	23.3	2.3	53.3	5
Okhale-1	6	1	3.7	2	18.3	1.3	28.3	3.3
GBK011127	6	1.3	6	2.3	10	2	8.3	2.7
GBK027155	8.3	1	6	2.3	21.7	2.3	63.3	5
GBK011059	9	1	6	1.7	23.3	1.7	23.3	3.7
GBK033575	9	1	2.3	1.3	16.7	2	21.7	3
ACC 32	10	1.3	10	3	13.3	2.3	60	3.3
GBK000752	10	1.3	2.7	1.7	20	1.7	40	4
GBK031861	10	2.3	9.3	2.7	21.7	2.3	36.7	4
IE4115	10	1	3.7	1.3	25	2.3	36.7	4.7
KNE 629	10	1	8.7	2.3	16.7	2.3	43.3	3
Egerton	10	1	2	1	11.7	2	25	3.7
ACC 29	11.7	2	2	1	33.3	2.3	63.3	4.3
Busibwabo	11.7	1.7	1.3	1	10	1.7	23.3	2.3
GBK000409	11.7	1.3	2.6	1.3	10	1.7	23.3	2.3
GBK000414	11.7	1.3	2	1	10	2.3	43.3	2
GBK000458	11.7	1	7	2.3	23.3	1.7	71.7	2.7
GBK000487	11.7	1.3	11.7	2.3	40	2.3	43.3	6
GBK000513	11.7	1.3	2.7	1.3	18.3	1.7	53.3	4.7
GBK000702	11.7	2.3	8.7	2.3	33.3	3.7	43.3	4.3
GBK000766	11.7	1	10	2.7	21.7	1	25	5
GBK008349	11.7	1.3	11.7	2.3	11.7	2.3	11.7	3
GBK011098	11.7	1	2	1	25	3	85	4.7
GBK027076	11.7	1.3	6	1.3	5	1.7	11.7	2
GBK029713	11.7	1.3	2	1	26.7	3	66.7	4.7
GBK029819	11.7	1.3	11.7	2.3	36.7	3	36.7	5
GBK029837	11.7	1.7	3.7	1.3	23.3	2.3	20	4.3

GBK029850	11.7	1	4.3	1.6	10	1	23.3	2
GBK031890	11.7	2.7	8.7	2.3	11.7	2	46.7	3.7
GBK033332	11.7	1.3	8.7	5.7	20	1.3	16.7	3.3
GBK033433	11.7	1.7	2	1	10	2.3	26.7	2.7
GBK033576	11.7	1	6	1.3	43.3	3	26.7	7.3
GBK033605	11.7	1.3	5	1.7	11.7	2.3	16.7	3
GBK043065	11.7	1.7	2	1	8.3	2	16.7	3
GBK043069	11.7	1	3.7	1.7	10	1.7	26.7	3
GBK043115	11.7	1.3	2.7	1.3	23.3	3.3	26.7	5
GBK043161	11.7	2.3	4	2	23.3	2.3	26.7	5.7
GBK043185	11.7	1.7	18.3	3.3	63.3	3.3	50	8
GBK000463	13.3	1.3	2.7	1.7	36.7	1.3	50	5
GBK029739	13.3	1.3	10	2.3	16.7	2	16.7	3
GBK033474	13.3	1	6	2.3	40	1.7	53.3	6.7
GBK033551	13.3	1.3	2.3	1	46.7	1.7	53.3	6.3
GBK000361	16	1.3	8.7	3.6	16.7	1.6	50	3.7
GBK029869	16	1	2.3	1.3	10	1	23.3	2
GBK033592	16	3.3	8.7	4	46.7	2	93.3	7.7
Ikhulule	16	1.3	16.7	3.3	11.7	2	33.3	3
GBK000719	16	1.3	3.7	1	50	1.7	33.3	7.6
GBK000638	16.7	1.3	2.3	1.3	23.3	2.7	26.7	4.3
GBK000696	16.7	1.3	3.7	1.3	10	2.3	10	2.3
GBK000780	16.7	2	2	1	11.7	2.3	40	4
GBK028567	16.7	2.3	11.7	2.3	23.3	1.7	76.7	4.7
GBK029747	16.7	2	3.7	1.3	10	1	10	3
GBK033520	16.7	1.7	2	1	23.3	2.3	18.3	7
U-15	16.7	1.3	3	1.3	11.7	2	33.3	3.7
GBK001119	18.3	3	43.3	4.3	50	3	71.7	8
GBK000453	18.3	2.3	3	1.3	50	3.7	56.7	8.6
GBK000516	18.3	2.3	2.3	1	43.3	1.7	40	8
GBK000845	18.3	2	4	1.7	46.7	3.7	60	7.7
P-224	18.3	2.3	8.7	2.3	10	2	58.3	2
GBK029875	20	2.3	2.7	1.3	13.3	2	30	3.3
GBK033464	20	1.7	5	2	23.3	1.3	83.3	4.3
ACC 14	21.7	2	4	1.7	40	3	26.7	5
GBK000493	21.7	2	8.7	1.7	36.7	2.7	28.3	5
GBK000359	23.3	2	3	1.7	23.3	2	71.7	4.7
GBK000364	23.3	1.3	16.6	5	36.7	2.3	50	4.7
GBK000483	23.3	2.3	8.7	2.3	43.3	2.3	46.7	5.7
GBK000608	23.3	1.3	11.7	2.3	26.7	3	36.7	5
GBK000621	23.3	2.3	3.7	1.7	18.3	1	13.3	2.7

GBK001115	23.3	2.3	8.7	3.7	23.3	2.7	66.7	3.3
GBK043169	23.3	3	16.7	4.3	36.7	2.3	33.3	6
Koibatek	23.3	2	5	2	26.7	3.3	33.3	5.3
GBK008294	25	1.7	6	2.3	16.7	1.7	46.7	2.7
GBK011044	25	2	2	1	63.3	3.7	25	9
GBK033418	25	2.7	16.7	2.3	50	3	73.3	8.3
GBK040468	25	2	6	2.3	5	1.3	53.3	2.3
GBK043258	25	3.3	23.3	3.7	18.3	2	43.3	3.7
GBK000449	26.7	2.7	3.3	1.7	36.7	2.7	53.3	4.7
GBK000590	26.7	2.7	2.7	1.3	46.7	3	46.7	7.3
GBK033410	26.7	3	6	2.3	43.3	2	70	6.7
GBK033548	26.7	2.7	3.67	2	36.7	1	78.3	7.3
GBK033569	26.7	2.7	11.7	2.7	35	3	63.3	6.3
GBK036767	26.7	2.7	36.7	4.3	50	1.7	91.7	9
GBK000882	30	3	33.3	4	36.7	2.3	26.7	4.7
GBK000904	30	2.7	23.3	3.7	43.3	3.3	81.7	7.7
GBK043124	30	3	11.7	2.3	20	1.3	36.7	3.7
GBK036839	31.7	2.3	6	2.3	11.7	2	26.7	3.3
GBK000410	33.3	2.7	16.7	2.7	20	2.3	36.7	3
GBK011110	33.3	3.3	53.3	5	20	2	23.3	4
GULU-E	33.3	3.7	6	2	16.7	2.3	46.7	4.3
KNE 714	33.3	2	23.3	3.7	31.7	2.7	93.3	6.7
GBK000503	36.7	4	36.7	4.7	36.7	2.3	88.3	5.3
GBK027169	36.7	2.7	56.7	5.3	35	2.7	90	6.8
RANGE	**5-36.7**	**1.3-4**	**1.3-56.7**	**1-5.6**	**5-63.3**	**1.5-5.8**	**8.3-99.3**	**2.1-9.1**
MEAN	**16.38**	**1.8**	**10.3**	**2.16**	**25.12**	**2.19**	**42**	**4.65**
SE	**4.08**	**0.48**	**2.987**	**0.535**	**5.75**	**0.53**	**7.08**	**0.99**
%CV	**24.4**	**26.4**	**29**	**24.8**	**22.9**	**24.4**	**16.9**	**21.4**
LSD	**6.57**	**0.77**	**4.81**	**0.86**	**5.26**	**0.86**	**9.13**	**0.74**
P VALUE	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**

KEY: Sea-season, var-variety, *, **, ***-significant at 0.05, 0.01 and 0.001 respectively **SC**=susceptible check; **RC**=Resistant check, **Fi sev**=Finger severity, **Fi Inc** =Finger incidence, **SC**=susceptible check; **RC**=Resistant check.

APPENDIX 5: Physiological Maturity, Height and Area under disease progress curve in Alupe 2011 and 2012

			ALUPE SEASON ONE				ALUPE SEASON TWO			
VARIETY	**PHT**	**DM**	**%Fsev 1**	**%Fsev 2**	**%Fsev 3**	**AUDPC**	**%Fsev 1**	**%Fsev 2**	**%Fsev 3**	**AUDPC**
GBK011127	54	109	2.0	6.0	25.0	195	2.0	2.0	2.0	40
GBK000590	57	96	2.3	5.3	28.3	206	3.7	3.0	5.3	75
GBK000621	63	106	2.3	4.3	20.0	155	2.0	2.0	2.0	40
GBK008349	67	105	2.3	8.3	25.0	220	4.3	1.7	4.7	62
GBK011098	60	99	2.3	4.3	18.3	146	2.2	2.0	3.5	49
Ikhulule	77	105	2.3	5.3	26.7	198	1.7	3.0	5.0	64
GBK000359	67	96	2.7	7.7	40.0	291	2.3	2.3	3.3	51
GBK000503	60	90	2.7	6.0	28.3	215	2.7	4.3	5.7	85
GBK000592	61	113	2.7	7.3	21.7	195	2.0	1.7	2.0	37
GBK000719	68	104	2.7	5.7	20.0	171	3.3	2.7	2.7	57
GBK000815	58	107	2.7	5.0	23.3	180	3.0	1.7	3.3	49
GBK000865	71	107	2.7	6.7	16.7	164	4.0	1.3	2.0	43
GBK001119	51	97	2.7	6.7	35.0	256	9.0	2.0	4.0	85
GBK011110	68	105	2.7	6.7	28.0	221	2.0	1.3	2.3	35
GBK029739	70	105	2.7	6.3	26.7	210	2.0	2.7	2.7	51
GBK031861	64	100	2.7	6.3	30.0	227	4.3	2.3	2.7	58
GBK031890	75	104	2.7	7.0	30.0	234	1.7	2.0	2.3	40
GBK033433	69	104	2.7	6.0	26.7	207	2.0	2.0	4.3	52
GBK036839	52	105	2.7	4.3	20.0	157	2.0	2.7	2.3	49
GBK043115	64	106	2.7	6.7	28.3	222	4.7	1.3	2.7	50
GBK043145	74	100	2.7	8.3	25.0	222	1.3	3.0	4.7	60
GBK043161	72	101	2.7	6.3	23.3	193	1.5	1.5	2.5	35
GBK043258	69	106	2.7	5.7	25.0	196	2.0	1.3	2.3	35
GULU-E	66	102	2.7	7.0	18.3	175	1.7	2.3	2.0	42
U-15**(RC)**	65	95	2.7	6.3	33.3	243	2.7	1.7	3.0	46
ACC 29	66	100	3.0	6.7	21.7	191	3.7	2.0	3.7	57
ACC 32	69	101	3.0	6.0	26.7	209	1.7	1.3	3.7	40
Busibwabo	76	100	3.0	6.7	33.3	249	2.3	1.7	2.0	39
GBK000458	59	100	3.0	11.3	26.7	262	1.7	1.7	3.7	44
GBK000506	59	100	3.0	6.0	21.7	184	3.7	2.7	5.3	72
GBK000516	61	101	3.0	7.3	31.7	247	2.3	2.0	2.7	45
GBK000608	60	103	3.0	6.7	31.7	241	2.3	2.0	2.7	45
GBK000696	65	107	3.0	6.0	26.7	209	2.7	1.7	2.3	42
GBK000702	66	100	3.0	7.0	23.3	202	2.0	1.7	3.7	46

GBK000752	85	98	3.0	7.3	26.7	222	2.3	2.3	4.0	55
GBK001115	65	98	3.0	6.3	31.7	237	3.0	3.7	5.7	81
GBK011125	68	101	3.0	6.8	23.0	198	2.0	1.6	2.4	38
GBK027169	59	93	3.0	5.3	21.7	177	3.3	3.7	4.7	77
GBK029713	44	101	3.0	4.7	25.0	187	4.0	2.3	3.3	60
GBK029747	73	107	3.0	7.7	21.7	201	1.7	2.3	2.0	42
GBK029837	67	104	3.0	6.3	25.0	203	1.7	1.3	2.7	35
GBK029850	68	103	3.0	7.0	23.3	202	2.3	1.3	2.0	35
GBK033332	65	104	3.0	10.0	21.7	224	1.7	1.7	2.3	37
GBK033513	68	101	3.0	6.0	21.7	184	1.7	2.3	2.0	42
GBK033575	71	103	3.0	8.3	26.7	232	2.7	3.0	7.7	82
GBK033605	67	101	3.0	5.3	20.0	168	2.0	2.7	2.7	51
GBK043065	75	100	3.0	6.7	38.3	274	2.0	1.7	2.0	37
GBK043069	60	101	3.0	6.3	28.3	220	2.7	1.3	2.3	38
GBK043124	68	102	3.0	5.0	21.7	174	2.0	2.0	2.3	42
GBK043169	69	102	3.0	7.0	35.0	260	2.3	2.0	2.0	42
Egerton	77	102	3.0	10.0	35.0	290	2.0	1.7	2.3	39
GBK000409	63	101	3.2	7.5	29.2	237	2.2	2.0	3.8	50
GBK000364	72	101	3.3	6.7	38.3	275	2.3	2.7	3.0	54
GBK000453	60	96	3.3	7.7	36.7	277	2.3	1.7	2.7	42
GBK000463	74	98	3.3	5.7	30.0	224	4.0	2.3	2.7	57
GBK000487	63	101	3.3	7.7	30.0	244	4.7	2.3	2.7	60
GBK000493	76	97	3.3	6.7	36.7	267	2.0	2.0	3.0	45
GBK000638	57	103	3.3	7.7	25.0	219	1.7	1.7	3.0	41
GBK000766	65	100	3.3	8.7	25.0	229	2.7	2.0	3.7	52
GBK000845	62	95	3.3	6.7	35.0	259	4.0	4.3	6.7	97
GBK000904	59	91	3.3	7.3	35	265	3.3	3	4.7	70
GBK011059	69	101	3.3	7.7	23.3	210	4.0	2.0	4.3	62
GBK028567	58	98	3.3	7.7	33.3	260	1.7	1.7	3.7	44
GBK029819	57	103	3.3	7.7	35.0	269	1.7	1.7	3.3	42
GBK029875	73	101	3.3	6.0	25.0	202	2.3	1.7	2.0	39
GBK033410	67	91	3.3	8.7	33.3	270	2.3	2.3	7.7	73
GBK033418	65	98	3.3	6.3	38.3	271	2.7	1.7	2.3	42
GBK033474	69	105	3.3	9.0	36.7	290	1.7	1.7	3.7	44
GBK033551	58	100	3.3	6.7	41.7	292	2.0	1.3	2.3	35
GBK033576	70	104	3.3	7.3	21.7	198	2.7	1.7	2.0	41
GBK040468	76	103	3.3	7.0	31.7	245	4.0	2.0	4.3	62
GBK043185	66	104	3.3	6.3	26.7	213	3.0	3.3	2.3	60
KOIBATEK	75	100	3.3	7.7	35.0	269	2.7	1.7	4.7	54
ACC 14	69	105	3.7	7.7	23.3	212	1.7	1.7	3.3	42
GBK000361	66	102	3.7	6.3	33.3	248	4.0	1.7	3.3	54
GBK000414	70	101	3.7	6.0	23.3	195	2.7	1.3	3.3	43
GBK000449	64	92	3.7	6.7	41.7	294	1.7	1.7	3.3	42

GBK000483	67	100	3.7	7.0	30.0	239	2.0	3.3	4.0	63
GBK000678	71	102	3.7	7.0	30.0	239	4.0	2.3	2.7	57
GBK000780	70	102	3.7	8.3	31.7	260	2.3	2.0	2.3	43
GBK000882	67	101	3.7	9.7	43.3	332	2.7	2.0	2.0	44
GBK011044	64	105	3.7	11.3	33.3	298	2.3	1.7	2.3	40
GBK027076	55	112	3.7	12.7	20.0	246	2.7	1.7	2.0	41
GBK029869	72	102	3.7	6.7	23.3	202	2.3	2.0	2.3	43
GBK033464	60	91	3.7	8.0	35.0	274	1.7	2.3	6.0	62
GBK033520	69	101	3.7	6.3	18.3	173	3.0	1.7	2.3	44
GBK033569	71	100	3.7	7.3	40	292	2.7	1.7	2.3	42
GBK033592	64	92	3.7	7.3	36.7	275	3.0	3.0	3.7	64
GBK036767	54	94	3.7	8.7	40.0	306	3.7	3.3	3.3	68
GBK039367	62	114	3.7	7.7	33.3	262	1.7	1.7	2.3	37
KNE 629	68	103	3.7	6.3	30.0	232	2.7	2.7	5	66
Okhale	65	103	3.7	11.3	26.7	265	4.3	2.0	3.3	58
P-224	63	101	3.7	7.7	31.7	254	1.7	4.0	3.0	64
GBK000513	60	100	4.0	8.7	30.0	257	3.0	2.3	5.3	65
GBK008294	67	102	4.0	13.3	30.0	303	3.3	2.0	2.3	48
GBK027155	77	100	4.0	9.0	30.0	260	2.7	1.3	2.3	38
IE4115	63	98	4.0	11.7	26.7	271	2.3	2.0	2.7	45
KNE 714**(SC)**	58	89	4.0	17.3	41.7	402	2.0	4.7	6.0	87
GBK033548	64	93	4.3	12.7	40.0	349	2.0	1.7	3.3	44

KEY: **PHT**=Plant height, **DM**=Days to maturity, **FSEV1**= Foliar severity I, **FSEV2**= Foliar severity 2, **FSEV3**= Foliar severity 3, **AUDPC**=Area under disease progress curve, **SC**=susceptible check; **RC=**Resistant check.

APPENDIX 6: Physiological Maturity, Height and Area under disease progress curve in Kakamega 2011 and 2012.

KAKAMEGA SEASON ONE							KAKAMEGA SEASON TWO			
VARIETY	**Pht**	**Dm**	**%Fsev 1**	**%Fsev2**	**%Fsev3**	**AUDPC**	**%Fsev 1**	**%Fsev2**	**%Fsev3**	**AUDPC**
GBK000458	54	114	2.0	3.0	4.7	64	11.7	5.0	2.3	120
GBK011125	71	118	2.0	3.0	5.7	69	9.3	6.7	3.0	129
GBK043065	75	111	2.0	3.0	5.0	65	5.0	4.7	2.0	82
ACC 14	84	116	2.3	3.7	10.0	99	9.3	6.7	3.0	129
Busibwabo	76	111	2.3	3.3	6.7	78	6.0	4.0	1.7	79
GBK000463	79	109	2.3	3.3	9.0	90	15.0	8.0	2.7	169
GBK000487	62	117	2.3	4.7	6.0	89	8.7	4.3	1.7	95
GBK000608	60	111	2.3	3.3	7.3	81	7.0	7.7	2.7	126
GBK000845	67	112	2.3	3.3	5.7	73	5.0	5.3	2.3	90
GBK008349	78	111	2.3	3.3	7.7	83	5.0	5.0	1.7	84
GBK027076	58	120	2.3	3.3	7.7	83	4.3	4.3	1.7	73
GBK028567	55	104	2.3	3.3	7.0	80	31.7	19.3	7.7	390
GBK029869	65	116	2.3	3.3	6.7	78	6.0	5.7	3.0	102
GBK029875	73	112	2.3	3.7	7.0	77	6.0	4.3	2.3	85
GBK033433	71	119	2.3	3.7	6.7	82	6.0	6.0	2.3	102
GBK033513	68	125	2.3	3.7	7.0	84	9.3	6.7	2.3	125
GBK033551	64	112	2.3	3.7	7.7	87	7.7	3.0	1.3	75
GBK043145	81	111	2.3	3.0	7.0	77	8.7	7.0	2.3	125
GULU-E	62	112	2.3	3.7	7.0	84	6.0	4.7	1.7	86
IE4115	57	113	2.3	3.0	5.3	68	5.0	4.7	2.0	82
P-224	64	111	2.3	3.3	8.0	85	7.7	8.3	3.0	137
ACC 29	63	119	2.7	3.7	7.0	86	6.0	6.3	3.3	110
GBK000359	79	110	2.7	4.0	8.0	94	9.3	7.0	2.7	130
GBK000364	78	112	2.7	3.3	8.0	87	7.0	6.0	2.7	109
GBK000483	57	111	2.7	4.0	8.3	95	6.7	7.0	2.3	115
GBK000493	79	109	2.7	3.7	8.3	92	11.7	7.7	3.0	151
GBK000621	59	110	2.7	3.7	8.0	91	20.0	16.7	5.0	292
GBK000702	69	107	2.7	3.7	12.3	112	6.0	5.7	2.3	99
GBK000719	58	107	2.7	3.3	8.3	88	11.0	11.7	4.3	194
GBK000865	74	122	2.7	3.0	7.7	82	7.0	7.7	3.3	129
GBK008294	61	110	2.7	3.7	12.0	111	11.0	12.3	2.7	192
GBK011059	60	115	2.7	3.0	7.3	80	7.7	7.7	3.0	131
GBK011127	60	132	2.7	3.3	6.3	78	6.0	3.7	2.0	77
GBK027155	82	112	2.7	4.7	7.0	96	11.7	8.7	4.3	167
GBK029747	72	110	2.7	3.3	8.7	90	7.0	6.0	2.7	109

GBK029837	64	118	2.7	3.3	6.3	78	5.0	6.3	2.3	100
GBK029850	60	124	2.7	3.3	7.0	82	7.0	6.7	2.7	116
GBK031890	82	117	2.7	3.0	6.3	75	5.0	8.7	3.3	129
GBK033418	70	106	2.7	3.7	8.7	94	33.3	25.0	8.7	460
GBK033464	60	105	2.7	3.7	10	101	18.3	8.0	3.3	188
GBK033548	65	108	2.7	4.0	8.0	94	9.3	6.3	2.7	123
GBK033569	71	111	2.7	5.0	12.0	124	6.0	5.3	1.3	90
GBK033576	73	118	2.7	3.0	4.0	64	6.0	4.3	1.7	82
GBK039367	86	124	2.7	4.0	7.7	92	9.3	5.7	2.0	114
GBK043115	63	121	2.7	4.3	12.3	118	35.0	22.7	7.7	441
GBK043161	55	111	2.7	3.3	7.7	85	13.3	10.0	4.7	190
Koibatek	79	111	2.7	3.7	9.7	99	11.7	9.3	3.3	168
Nakuru	80	117	2.7	3.3	10.0	97	7.0	6.0	2.7	109
Okhale	70	110	2.7	4.0	6.0	84	9.3	6.0	1.7	115
U-15**(RC)**	60	108	2.7	3.3	7.3	83	7.0	9.0	4.0	145
GBK000409	69	111	2.8	3.7	8.0	91	8.7	7.3	3.3	133
ACC 32	78	115	3.0	4.0	8.7	99	5.3	5.7	2.0	94
GBK000516	68	111	3.0	3.7	9.7	101	6.0	6.0	2.7	104
GBK000592	54	124	3.0	3.3	8.3	90	6.0	4.3	1.7	82
GBK000678	62	125	3.0	3.7	7.7	91	8.7	8.0	2.7	137
GBK000752	91	114	3.0	3.7	6.0	82	11.7	12.7	4.3	207
GBK000815	47	127	3.0	4.0	6.3	87	8.7	5.3	2.0	107
GBK000904	61	103	3.0	4.0	8.3	97	30.0	26.7	12.3	479
GBK011044	70	113	3.0	4.3	9.3	105	6.0	7.0	3.0	115
GBK027169	65	103	3.0	3.7	9.0	97	53.3	46.7	17.7	822
GBK029819	53	113	3.0	4.0	7.0	90	6.0	7.7	3.3	124
GBK033332	65	108	3.0	4.0	6.7	89	33.3	17.3	7.0	375
GBK033410	72	109	3.0	7.3	12.0	148	36.7	20.0	9.0	429
GBK033520	68	117	3.0	3.7	7.7	91	5.0	5.0	2.7	89
GBK033575	66	112	3.0	4.0	9.7	104	11.7	14.0	6.0	229
GBK033605	66	117	3.0	2.7	7.7	81	6.0	3.7	1.3	74
GBK036767	53	110	3.0	4.0	7.7	94	36.7	30.0	11.0	539
GBK036839	66	111	3.0	5.3	7.7	107	6.0	6.7	3.0	112
GBK043069	65	124	3.0	3.3	7.3	85	7.0	5.0	2.0	95
GBK043124	78	111	3.0	4.3	9.0	103	9.3	8.7	2.3	145
KNE 629	64	113	3.0	3.7	9.7	101	6.0	4.3	2.0	83
KNE 714**(SC)**	65	112	3.0	5.0	9.3	112	10.0	8.7	3.0	152
GBK011098	69	111	3.2	5.5	9.7	120	4.3	5.3	2.7	88
GBK000361	60	115	3.3	3.7	9.0	99	5.0	3.7	1.7	71
GBK000449	60	106	3.3	3.7	6.7	87	36.7	21.7	9.7	449
GBK000453	59	108	3.3	3.7	8.3	95	25.0	13.3	3.7	277
GBK000503	62	102	3.3	3.7	10.7	107	36.7	30.0	11.3	540
GBK000506	58	116	3.3	3.3	7.0	85	10.3	9.3	3.0	160

GBK000638	80	108	3.3	3.3	9.0	95	4.3	6.0	2.3	93
GBK000696	61	119	3.3	3.3	6.3	81	11.7	7.7	3.0	151
GBK000766	60	124	3.3	3.7	6.3	85	8.7	8.3	2.7	140
GBK000882	66	101	3.3	5.0	9.3	113	26.7	38.3	14.3	588
GBK001115	62	104	3.3	3.7	11.0	109	23.3	15.3	5.3	296
GBK011110	69	103	3.3	3.7	12.0	114	16.7	12.3	3.7	225
GBK029713	58	121	3.3	3.7	7.3	90	8.7	5.3	1.7	105
GBK029739	62	115	3.3	3.3	9.0	95	7.0	7.0	2.7	119
GBK031861	69	112	3.3	4.0	8.7	100	6.0	6.0	2.0	100
GBK033474	75	113	3.3	3.3	5.7	78	5.0	4.7	2.3	84
GBK033592	67	108	3.3	4.0	6.7	90	13.3	13.3	4.0	220
GBK040468	61	107	3.3	3.7	8.0	94	30.0	31.7	13.3	534
GBK043169	75	109	3.3	4.3	12	120	13.3	10.0	5.0	192
GBK043258	62	112	3.3	3.7	6.3	85	11.7	15.0	7.0	244
Ikhulule	75	114	3.3	3.3	8.0	90	9.3	10.7	4.0	174
GBK000414	68	116	3.7	5.0	9.3	115	8.7	9.7	3.7	159
GBK000513	58	110	3.7	5.3	10.7	125	6.0	5.3	2.7	97
GBK000590	52	106	3.7	3.7	8.3	97	10.0	6.3	3.0	128
GBK000780	77	115	3.7	4.0	12.3	120	10.0	5.3	2.3	115
GBK043185	83	113	3.7	3.3	6.7	85	11.7	8.3	3.0	157

KEY: **PHT**=Plant height, **DM**=Days to maturity, **FSEV1**= Foliar severity I, **FSEV2**= Foliar severity 2, **FSEV3**= Foliar severity 3, **AUDPC**=Area under disease progress curve, **SC**=susceptible check; **RC=**Resistant check.

APPENDIX 7: Yield and yield component scores for 100 finger millet varieties under field conditions in Alupe 2011 and 2012

Alupe 2011 (season one)						Alupe 2012 (season two)				
variety	DF (days)	DM (days)	PHT (cm)	% LGN	TLRS	DF (DAYS)	DM (days)	PHT (cm)	%LGN	TLRS
GBK000904	55	93	52.3	6.3	4	61	89	65.7	4.7	3
KNE 714(**SC**)	59	90	45	5.7	3	59	87	70.7	1.3	6
GBK000503	61	89	48.7	6.3	4	60	90	70.3	2.7	3
GBK033410	61	93	55.3	5.3	3	59	90	78.7	6	4
GBK033548	62	91	56	7.3	3	67	96	72.7	2	4
GBK000882	63	94	47.3	2.3	11	77	107	86.3	6	3
GBK001115	64	96	54	6.7	3	61	99	76	4.3	3
U-15(**RC**)	65	95	48.7	4.3	2	66	96	81	3	2
GBK027169	66	96	47	5.3	4	61	90	71.3	3.3	6
GBK033464	66	92	46	4.3	3	65	91	73.3	3.7	3
GBK000590	67	99	45	4..0	3	61	92	68.3	2.7	2
GBK000453	67	91	51.3	4.7	4	69	101	68.7	1	3
GBK000702	67	95	49.7	5.7	4	69	104	82.3	2.7	3
GBK000752	67	91	69.7	8.7	5	71	104	100.7	90	3
GBK033418	67	96	50	4.7	3	69	100	80.3	1.3	3
GBK000449	68	94	50.7	7.3	4	65	91	78	3.7	3
GBK000359	68	96	51.7	4	3	66	95	82.7	2.7	2
GBK000493	68	92	57.7	4.7	3	69	102	95	3	2
GBK000845	68	94	44.7	4.3	4	62	96	79	4.3	3
GBK000463	69	92	61	5.7	3	70	103	86.3	12	3
GBK033569	69	98	54.3	5.7	4	71	101	88.3	4.7	3
GBK043169	69	97	49.7	2	5	74	106	88	26.7	3
Koibatek	69	97	59	5.3	3	71	102	90	26	3
Busibwabo	69	95	65.3	8	5	74	105	86.7	50	3
GBK000483	70	97	52.7	4.3	4	72	103	81.7	2	3
GBK043065	70	97	60.3	6.3	4	72	104	90.3	83.3	3
GBK043145	70	97	59.7	5.3	3	70	103	87.7	8.7	4
IE4115	70	98	52.3	5	3	70	98	73	1.3	3
GBK033551	71	96	39.7	4	2	74	103	75.7	1.3	3
GBK000410	71	97	44.3	3.7	4	73	104	68	5	4
GBK000458	71	99	45.7	3.3	4	70	102	72	1	4
GBK029819	71	99	44.7	3.7	4	72	106	69	2	2
GBK027155	71	98	53.3	7	3	72	102	99.7	25	4
GBK028567	71	99	45.7	4	4	69	96	71	1.3	4
GBK029875	71	97	58.7	4.3	3	74	105	86.3	3	3

GBK033592	71	97	51	1.7	9	61	87	76.7	2	5
GBK043124	71	98	55.7	6	4	70	105	80.3	26.7	3
Okhale-1	71	99	43	7.3	3	76	107	87.7	36.7	4
GBK000364	72	97	57.7	2.7	5	73	105	86.3	6.7	2
Egerton	72	98	65.7	7	4	75	105	88.7	86.7	3
P-224	72	98	51.7	7.3	3	73	104	74.3	4	3
GBK000513	72	98	51.7	4.3	3	71	101	67.7	1.7	2
GBK001119	72	97	38.7	3.3	4	73	98	76	3	3
GBK036767	72	97	39.7	3	5	61	90	68.7	1	5
GBK031861	72	98	51	5.3	3	69	102	76	7	3
GBK033474	72	106	58.7	3	2	74	104	78.3	2	2
GULU-E	72	98	54.7	4	3	71	106	77.3	1	3
GBK000608	73	99	47	5.3	3	72	106	72.7	1	3
GBK000780	73	99	49	5	3	75	105	90	30	3
GBK000516	73	99	46.7	4.7	3	71	104	76	1.3	3
GBK000409	74	98	56.3	5	3	71	103	84	5.7	3
GBK008294	74	100	50	5.7	3	70	104	84.7	2.3	3
GBK043161	74	97	64.3	4	5	70	103	86	9	3
GBK011098	74	99	40.3	3.7	5	68	100	63.3	0.7	3
GBK033513	74	96	48.3	3.7	3	83	107	87.7	0.7	2
GBK000414	75	98	51.7	1.7	4	72	105	87.7	10	3
GBK000506	75	99	45.7	3	3	71	101	71.3	1.3	3
GBK029850	75	99	48.3	2	3	80	107	88.3	2	3
GBK029869	75	97	61.3	4	3	75	106	83.3	2.3	3
GBK031890	75	101	61	6	2	73	106	88	4.3	3
GBK000487	76	99	48.7	4.7	3	71	102	77	1	3
ACC 32	76	99	55.3	3.7	3	72	102	83.3	1.7	3
GBK011059	76	99	53.7	4.3	4	78	104	85	24.7	3
GBK029713	76	98	31	0.7	6	74	104	57	4.7	3
GBK033575	76	103	52.3	4.3	3	73	103	88.7	2.3	2
ACC 29	77	97	39.7	2.7	3	75	102	92	1.7	3
GBK011044	77	105	42	1.3	5	79	104	85	16.3	3
KNE 629	77	103	51.7	3.7	3	77	102	83.7	1.3	2
GBK000361	78	98	46	2.7	3	73	105	86.7	53.3	3
GBK029837	78	102	56.3	4.3	4	77	105	77	2.3	3
GBK011125	78	103	56.3	4	3	79	106	83.7	4	3
GBK033576	78	100	47	2	4	78	107	92.3	15.3	3
GBK040468	78	99	59	3.3	3	78	107	93.7	30	3
GBK029747	79	107	50.3	1.3	4	79	107	95.3	1.7	3
GBK000766	79	94	41.7	4.7	3	76	106	87.3	5.7	3
GBK043069	79	98	45.3	1.7	3	77	105	74.7	1	3
Ikhulule	79	104	63.7	4	3	73	105	89.3	4.3	3
GBK000678	80	99	53.3	4	3	79	105	88	1.3	3

GBK033332	80	102	39.7	2	4	78	106	90	5.7	3
GBK033605	80	97	47.7	2	3	78	105	86	0.3	3
GBK033433	81	102	52.7	3.3	2	71	105	84.7	2	3
GBK033520	81	95	60.7	2	4	77	106	76.7	1	3
GBK000719	81	101	46	2.7	3	78	107	90.3	4.3	3
GBK000638	82	101	33	2.3	3	75	105	80.3	20.3	3
GBK011110	82	103	49.7	3.7	3	78	107	86.7	6	2
GBK043185	82	103	53	2.7	4	72	106	79	1	2
ACC 14	82	104	42.7	2.3	3	74	106	94.3	1.3	3
GBK000696	82	106	48	3	3	80	107	81.3	0.7	2
GBK029739	82	102	54	1.3	6	81	107	86	2	3
GBK043115	82	104	45.7	2.7	2	79	107	82.7	1.7	3
GBK000621	83	105	44	1	2	80	107	81	1.7	2
GBK000865	83	107	51.7	2	3	78	106	90.7	0.7	3
GBK008349	83	103	45.7	3	2	81	107	88	26.7	3
GBK043258	83	105	49	1.7	5	75	107	89	5.3	3
GBK011127	85	103	45.7	1.3	3	87	98	76	0.7	3
GBK036839	85	107	27.7	0.7	8	72	104	76	1.3	3
GBK000815	89	111	35	1.3	3	70	104	81.3	5	3
GBK027076	93	118	34.3	1	6	87	107	75	1	5
GBK000592	95	118	42.7	1.3	4	84	109	78.3	1.3	5
GBK039367	97	121	40	1.7	4	76	107	83.3	18.3	4
RANGE	**31-113**	**72-134**	**21-74**	**0-10**	**1-16**	**57-90**	**80-110**	**51-112**	**0-90**	**1-10**
MEAN	**74.26**	**99.16**	**49.88**	**3.907**	**3.61**	**72.6**	**102.5**	**81.52**	**9.3**	**3.06**
%CV	**7.7**	**5.9**	**15.9**	**23.4**	**37**	**3**	**2.9**	**8.2**	**94.2**	**32**
LSD	**9.21**	**9.44**	**12.8**	**1.47**	**2.15**	**3.5**	**4.86**	**10.73**	**14.11**	**1.58**

KEY: **PHT**=Plant height, **DM**=Days to maturity, **FSEV1**= Foliar severity I, **FSEV2**= Foliar severity 2, **FSEV3**= Foliar severity 3, **AUDPC**=Area under disease progress curve, **SC**=susceptible check; **RC=**Resistant check.

APPENDIX 8: Yield and yield component scores for 100 finger millet varieties under field conditions in Kakamega 2011 and 2012.

	Kakamega 2011 (season one)					Kakamega 2012 (season two)				
variety	DF (days)	DM (days)	PHT (cm	% LGN	TLRS	DF (days)	DM (days)	PHT (cm)	% LDGN	TLRS
GBK000882	72	106	58	14	8	68	95	74	63.3	4
GBK033592	72	106	59.3	16.7	6	65	109	74	53.3	3
GBK011110	73	107	55	17.3	7	70	99	83.7	66.7	4
GBK036767	73	106	39.3	20	10	72	101	66	53.3	4
KNE 741	74	109	51	16.7	12	74	115	79.3	53.3	5
GBK033418	75	107	52.7	4.3	5	77	105	87.7	11.7	4
GBK000590	75	107	44.3	2	5	76	104	60.3	3.7	4
GBK001115	75	106	50.7	10.3	5	70	101	73.3	47.7	5
GBK000449	76	107	46.3	1.3	3	77	105	73.3	7.7	5
GBK000503	76	107	53.3	26.7	8	62	96	71	26.7	5
GBK033464	76	108	46.3	8.3	5	76	101	73.7	50	5
GBK000410	77	107	58.3	11	5	77	106	77	53.3	5
GBK040468	77	107	50.3	10.7	5	76	106	71.3	11.7	6
GBK000904	77	109	54.7	10.3	7	71	97	68	50	4
GBK033410	77	110	59	10.3	5	82	109	84.3	16.7	4
GBK000483	77	116	47.3	2	5	77	105	66.7	5.3	6
GBK000463	78	110	63.7	7	4	78	108	94.3	70	4
GBK043169	78	110	58	4.7	3	86	108	91.3	21.7	5
ACC 32	78	113	60.3	10.7	3	87	117	94.7	33.3	5
GBK029875	78	111	59.3	4.7	4	84	113	86.3	26.7	6
GBK033548	78	109	55.3	16.7	5	77	106	74.3	33.3	3
KNE 629	78	111	45.7	4	3	86	114	82.3	9.3	5
GBK000702	78	108	61	7.7	5	76	106	77.3	23.3	7
GBK008294	78	110	41.7	7.3	4	81	110	80.3	16.7	4
GBK000638	79	109	66	14	5	77	106	94	93.3	7
GBK000513	79	112	43.7	2.7	4	79	108	71.3	3	4
GBK011059	79	113	39.3	8	3	91	116	80.3	4.3	4
GBK027169	79	111	53	23.3	9	64	94	76.3	50	4
GBK000845	80	113	53.7	7	5	80	110	80	33.3	5
U-15	80	111	45.7	13.3	4	74	104	74.7	10	5
GBK043065	80	112	63	11	4	82	110	86	76.7	5

GBK043161	80	112	50.7	2	4	79	110	89	63.3	5
GBK043185	80	111	58.3	10.3	4	82	114	108	60	6
GULU-E	80	112	49.3	7	3	80	111	74.7	3.7	4
IE4115	80	115	43.7	2	4	86	111	70.7	5	4
Koibatek	80	113	61.3	13.7	4	81	110	96	73.3	6
Okhale	80	110	51	1.3	3	82	110	89.3	23.7	5
GBK000359	80	113	59.3	5	6	78	106	98.7	46.7	4
GBK000453	80	110	45.7	4.7	4	81	107	72.3	11.7	5
GBK000487	80	115	45.3	1.7	3	91	119	78	3.7	5
GBK029747	80	112	61.3	17	5	78	107	82	66.7	5
GBK031861	80	112	52.7	2.3	4	81	112	85	33.3	4
GBK033332	80	109	47.7	1.3	2	78	107	81.7	13.3	4
GBK000361	81	114	56	17	3	85	115	63.7	53.3	4
GBK000516	81	113	55.7	4.7	3	82	109	81	3.7	5
GBK000719	81	113	46.7	1.3	4	73	101	68.7	15	4
P-224	81	113	48	4	3	80	108	80	33.3	5
GBK008349	81	110	63.7	8	3	83	112	93	63.3	4
GBK033575	81	114	49.3	2	2	83	110	82	4.7	5
GBK000364	81	113	57	4.7	3	82	112	99	30	6
GBK000608	81	113	43	2.3	5	84	110	77.3	4.3	5
GBK029837	81	114	43.3	1.3	2	91	121	83.7	3.7	3
GBK033605	81	115	47.7	1.3	3	88	120	84	3.7	6
GBK043145	81	113	60	7	2	80	109	102.7	80	6
GBK000621	82	113	44	1.3	4	79	107	73	11.7	6
GBK033551	82	113	42.3	7	3	83	111	85.3	4.3	4
Busibwabo	82	115	66.3	16.7	5	79	108	86.3	73.3	6
GBK011098	82	114	62	13.3	4	81	110	82.3	42.7	6
GBK000696	82	116	43.3	4.3	3	89	121	79	3	4
GBK033569	83	115	58.7	7.3	7	79	108	83.7	60	5
GBK043124	83	112	71.3	10.3	8	80	109	84.3	66.7	6
Ikhulule	83	115	48.3	2	3	82	113	101	30	5
GBK000493	83	109	62.7	4	7	77	108	96	25	4
GBK011044	83	115	53.7	17	5	82	111	86.3	86.7	7
GBK027155	83	115	62	10.3	4	80	108	101.7	76.7	5
GBK028567	83	114	43	1.7	3	79	107	66.3	11.7	5
GBK029819	83	115	37.3	4.7	3	84	111	69.3	6	4
GBK036839	83	114	54.7	4.7	4	81	108	77	12.7	5
ACC 14	83	113	70	4.7	3	86	118	97.3	6	5
GBK000119	83	114	47	10.3	3	81	107	84	53.3	5
GBK033576	83	116	49.3	1.7	3	90	120	96	6.7	6
GBK000458	84	116	40	2	4	80	112	68.7	2.3	6

GBK029739	84	116	48.7	10	4	83	114	75	22.3	6
GBK033520	84	115	51	7.3	3	88	118	85	5	5
GBK000752	84	116	66.3	30	5	79	111	114.7	96.7	5
GBK031890	84	117	61.3	7.3	4	87	118	103	40	5
GBK033474	84	116	55.3	4.3	6	85	110	95.3	3.7	4
GBK000506	84	118	39.3	1	2	87	114	75.7	3.7	5
GBK011125	84	118	55	2	5	89	119	87	11.7	6
Egerton	84	115	61.3	16.7	5	84	118	99.3	70	5
GBK000409	85	116	59	11	3	82	114	82.3	33.3	5
GBK027076	85	118	35	1	4	93	123	80.3	3	13
GBK000780	85	116	59.7	8.7	3	84	114	94.7	56.7	5
GBK000414	86	117	48.7	7	6	84	115	87.7	28.3	5
GBK029869	86	119	47	1.3	3	85	114	82	13.3	5
GBK033433	89	121	47	1.3	3	88	117	94.7	4.3	5
GBK043258	89	119	50.7	7.7	5	78	105	74	25	4
GBK000592	90	123	27.7	2.7	2	86	126	79.3	3	8
GBK000865	92	122	38.7	4.7	2	89	121	109.3	15	5
ACC 29	93	125	41	4	3	85	113	85.3	6.7	6
GBK000678	93	119	33.3	1.3	1	99	130	90.3	2.3	4
GBK029713	96	128	35	1	2	85	114	80	6	8
GBK033513	96	125	45	2	2	95	125	91.3	5	5
GBK000766	97	129	36.7	2	3	88	119	83	2.3	5
GBK043115	98	127	35	2.7	3	87	114	90	18.3	4
GBK029850	98	124	35.7	1.3	2	96	124	84.7	5	5
GBK000815	99	131	19	1.3	3	79	122	75.3	27.3	11
GBK043069	99	126	40.7	7	2	91	121	88.7	4.3	5
GBK039367	105	131	76.3	8	1	92	117	95	20	6
GBK011127	106	135	34.7	2.7	2	102	128	84.3	1.7	4
RANGE	**70-110**	**104-136**	**17-78**	**1-40**	**1-19**	**59-106**	**93-133**	**17-121**	**1-100**	**2-15**
MEAN	**82.6**	**114.4**	**50.7**	**7.26**	**4**	**82**	**111.3**	**83.5**	**29**	**5.1**
%CV	**7.4**	**4.1**	**4.8**	**89**	**39.1**	**3.8**	**3.2**	**9.5**	**56.8**	**25.6**
LSD	**9.9**	**7.59**	**3.93**	**10.42**	**2.57**	**5**	**5.75**	**12.77**	**26.4**	**2.1**

KEY: PHT=Plant height, DF= Days to flowering, DM=Days to maturity, TLRS=No of tillers, LDGN=Lodging, SC=**susceptible check;** RC=**Resistant check.**

APPENDIX 9: Analysis of variance (ANOVA) for yield and disease for finger millet varieties in Kakamega, Kenya 2011/ 2012

		Mean squares											
Source of variation	**DF**	**F sev**	**F inc**	**Nsev**	**N inc**	**Psev**	**P inc**	**DF**	**Dm**	**Pht**	**Yld**	**Tlrs**	**Ldgn**
Env	1	10914.3	22.2	94004.7	545.4	120360.3	614.9	23221.6	43320.1	609.2	1426	472.3	39571.6
Blocks	2	46.4	2.8	135.8	1.5	39.1	0.01	34.8	80.8	596.2	11868	11.7	17
Genotypes	100	151.2	1.7	1237.3	6.7	1298.1	7.9	375.2	250.3	552.5	10890	7.6	1385.5
Gen*Env	98	79.7	0.7	564.4	2.8	583.1	3.395	76.4	84.5	155.9	7973	3.2	489
Season	1	35046.0	112.4	45.2	421.3	8143.2	586.6	467.7	4.1	311535	9826731	15.2	54850.6
Rep*season	2	105.53	1.33	230.5	8.7	459.5	2.1	29.1	165.4	45.1	54053	5.2	687.2
Error	996	92.43	0.55	152.7	1.3	142.7	1.3	25.3	27.1	67.1	3950	2.8	215.7

KEY: * significant at 0.05 probability level; ** significant at 0.01 probability level; ns not significant, **SEV** =foliar severity **INC**= folia incidence, **N SEV**= neck severity, **N INC**= neck incidence, **PSEV**=panicle severity, **PINC**= panicle incidence, **DF**=Days to flowering; **DM**=Days to maturity; **PHT**=Plant height (cm); **YLD**=Grain yield Kg ha^{-1} ,**TLRS**=no of tillers, **LDGN**= % lodging,; Rep*SEASON=replicate interaction within season, **GEN*ENV**=genotype interaction within environment.

APPENDIX 10: Analysis of variance (ANOVA) for yield and disease for finger millet varieties in Alupe, Kenya 2011/ 2012

		Mean squares											
Source of variation	**DF**	**Fsev**	**F inc**	**N sev**	**N inc**	**Psev**	**P inc**	**DF**	**Dm**	**Pht**	**Yld**	**Tlrs**	**Ldgn**
Env	1	10914.3	22.2	94004.7	545.4	120360.3	614.9	23221.6	43320.1	609.2	1426	472.3	39571.6
Blocks	2	46.4	2.7	135.8	1.5	39.1	0.01	34.8	80.8	596.2	11868	11.7	17
Genotypes	100	151.2	1.7	1237.3	6.6	1298.1	7.9	375.2	250.3	552.5	10890	7.6	1385.5
Gen*Env	98	79.7	0.7	564.4	2.8	583.1	3.4	76.4	84.5	155.9	7973	3.2	489
Season	1	35046	112.4	45.2	421.3	8143.2	586.6	467.7	4.1	311535.1	9826731	15.2	54850.6
Rep*Season	2	105.5	1.3	230.5	8.7	459.5	2.1	29.1	165.4	45	54053	5.2	687.2
Error	996	92.4	0.5	152.7	1.3	142.7	1.3	25.3	27.1	67.1	3950	2.8	215.7

KEY: * significant at 0.05 probability level; ** significant at 0.01 probability level; ns not significant, **FSEV** =folia severity **F INC**= folia incidence, **N SEV**= neck severity, **N INC**= neck incidence, **PSEV**=panicle severity, **PINC**= panicle incidence, **DF**=Days to flowering; **DM**=Days to maturity; **PHT**=Plant height (cm); **YLD**=Grain yield Kg ha^{-1} ,**TLRS**=no of tillers, **LDGN**= % lodging,; **Rep*SEASON**=replicate interaction within season, **GEN*ENV=**genotype interaction within environment

APPENDIX 11: Analysis of variance (ANOVA) for yield and yield traits for finger millet, Kakamega, Kenya, 2011/ 2012

	Mean squares											
Source of variation	**DF**	**F sev**	**F inc**	**N sev**	**N inc**	**Psev**	**P inc**	**DF**	**Dm**	**Pht**	**Yld**	**Tlrs**	**Ldgn**
Blocks	2	17.4	0.7	357.3	3.8	20.4	2.1	113.3	14.8	292.4	31869	9.3	248.8
Genotypes	99	161.9	1.3	424	2.8	475	3.7	228	211.7	447.6	10925	6.7	1406.1
Genotypes*Season	99	131.8	0.7	154.7	1.1	204.4	1.5	45.8	40	195.1	3778	9.1	753
Season	1	2269.8	1.4	35037	7	6266.2	17.7	104.1	1398.4	161441.6	3684017	150	70286.7
Rep*Season	2	7.6	0.02	374.4	3.4	71.4	2.2	4	17.8	175.7	10580	14	1802.9
Error	396	6.1	0.3	14	0.3	12.8	0.3	23.6	17.5	34.5	1887	2.1	155.6

KEY: * significant at 0.05 probability level; ** significant at 0.01 probability level; ns not significant, SEV =folia severity INC= folia incidence, N SEV= neck severity, N INC= neck incidence, PSEV=panicle severity, PINC= panicle incidence, **DF**=Days to flowering; **DM**=Days to maturity; **PHT**=Plant height (cm); **YLD**=Grain yield Kg ha^{-1} ,TLRS=no of tillers, LDGN= % lodging,; **Rep*SEASON**=replicate interaction within season.

APPENDIX 12: Analysis of variance (ANOVA) for yield and yield traits for finger millet during short rain in Kakamega, Kenya, 2011

	Mean squares											
Source of variation	DF	F sev	F inc	N sev	N inc	Psev	P inc	DF	Dm	Pht	Yld	Tlrs	Ldgn
Blocks	2	1.2	0.1ns	731.3	6.4	46.8	0.01	68.2	31.7	8.2	22802.9	4.2	404.7
Genotypes	99	10.8	0.3ns	142.4	1.1	196.5	1.6	133.3	107	300	3172.9	10.4	111.2
Error	198	3	0.2	22.8	0.2	16.7	0.2	37.6	22.2	5.9	716.6	2.6	41.9

KEY: * significant at 0.05 probability level; ** significant at 0.01 probability level; ns not significant, SEV =folia severity INC= folia incidence, **N SEV**= neck severity, **N INC**= neck incidence, **PSEV**=panicle severity, **PINC**= panicle incidence, **DF**=Days to flowering; **DM**=Days to maturity; **PHT**=Plant height (cm); **YLD**=Grain yield Kg ha^{-1},^{TLRS}=no of tillers, **LDGN**= % lodging.

APPENDIX13: Analysis of variance (ANOVA) for yield and yield traits for finger millet during long rain in Kakamega, Kenya, 2012

		Mean squares											
Source of variation	DF	F sev	Finc	N sev	N inc	Psev	P inc	DF	Dm	Pht	Yld	Tlrs	Ldgn
Blocks	2	23.8		0.4	0.8	44.9	4.4	49	0.9	459.9	19646	19	1647
Genotypes	99	282.9		436.3	2.8	482.8	3.7	140.5	144.7	342.7	11530	5.4	2047.9
Error	198	9.1		5.2	0.3	8.9	0.3	9.6	12.8	63	3057	1.7	269.4
Total	299												

KEY: * significant at 0.05 probability level; ** significant at 0.01 probability level; ns not significant, SEV =folia severity INC= folia incidence, **N SEV**= neck severity, **N INC**= neck incidence, **PSEV**=panicle severity, **PINC**= panicle incidence, **DF**=Days to flowering; **DM**=Days to maturity; **PHT**=Plant height (cm); **YLD**=Grain yield Kg ha^{-1}, **TLRS**=no of tillers, **LDGN**= % lodging.

APPENDIX 14: **Analysis of variance (ANOVA) for yield and yield traits for finger millet during short rain in Alupe, Kenya, 2011**

		Mean squares											
Source of variation	DF	F sev	F inc	N sev	N inc	P sev	Pinc	DF	Dm	Pht	Yld	Tlrs	Ldgn
Blocks	2	274.3	4.4	345.8	0.2	623	2.3		347.1	271.6	4244.9	6.6	4.7
Genotypes	99	123	0.8	579.9	1.8	475	1.3	158.7	85.4	177.9	1255.1	4.9	9.9
Error	198	27.5	0.5	25.8	0.3	33.1	0.3		34.4	63.2	349.1	1.8	0.8
total	299												

KEY: * significant at 0.05 probability level; ** significant at 0.01 probability level; ns not significant, SEV =folia severity INC= folia incidence, **N SEV**= neck severity, **N INC**= neck incidence, **PSEV**=panicle severity, **PINC**= panicle incidence, **DF**=Days to flowering; **DM**=Days to maturity; **PHT**=Plant height (cm); **YLD**=Grain yield Kg ha^{-1}, **TLRS**=no of tillers, **LDGN**= % lodging.

APPENDIX 15: Analysis of variance (ANOVA) for yield and yield traits for finger millet during long rain in Kakamega, Kenya, 2012

		Mean squares											
Source of variation	DF	F sev	F inc	N sev	N inc	Psev	Pinc	DF	Dm	Pht	Yld	Tlrs	Ldgn
Blocks	2	9.9	2.1	11.6	18.9	77.3	1.6	43.1	19.2	310.1	221535		173.4
Genotypes	99	5.4	0.9	1285.9	7.3	1532	10.2	104.9	81.6	203.7	14853	1.7	874.5
Error	198	0.7	0.2	52.1	0.9	50.15	1	4.7	9.1	44.4	6833		76.8
Total	299												

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nt at 0.05 probability level; ** significant at 0.01 probability level; ns not significant, SEV =folia severity INC= folia incidence, **N SEV**= neck severity, **N INC**= V=panicle severity, **PINC**= panicle incidence, **DF**=Days to flowering; **DM**=Days to maturity; **PHT**=Plant height (cm); **YLD**=Grain yield Kg ha^{-1}; **TLRS**=no dging.