EVALUATION OF RICE GENOTYPES FOR AGRONOMIC AND YIELD RELATED TRAITS

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DECLARATION

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

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DEDICATION

This work is dedicated to my mother Grace Rono, for her prayers, support and encouragement.

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ABREVIATIONS

ANOVA	Analysis of Variance
AUDPC	Area under disease progress curve
CAN	Calcium Ammonium Nitrate
DAP	Diammonium Phosphate
GCA	General Combining Ability
GPR	General Predictability Ratio
ICRC	Industrial Crops Research Centre
KALRO	Kenya Agricultural and Livestock Research Organization
MOA	Ministry of Agriculture
MT	Metric tons
NCD II	North Carolina Design II
SCA	Specific Combining Ability
SES	IRRI Standard Evaluation System
SPAD	Soil Plant Analysis Development

GENERAL ABSTRACT

The demand for rice in Kenya is high while production has remained far below consumption demand for quite a number of years. Growing of poorly adapted varieties with undesirable traits is one of the major factors limiting production. The specific objectives of this study were a) to determine the performance of rice cultivars for both agronomic and yield related traits and b) to determine the combining ability and heritability of agronomic and yield traits among the rice genotypes. Seven rice genotypes namely Basmati 370, Kuchum, Komboka, Mwur 4, Nerica 1, Duorodo and Nerica 4 were crossed in a North Carolina II mating design to generate F_1 hybrids. The 12 F_2 seeds, 7 parents and 1 check variety which made a total of 20 entries were planted at Kenya Agricultural and Livestock Research Organization -Mwea. Each genotype was planted in a plot size of 3 × 3 m, at inter-row spacing of 20 cm and intra spacing of 15 cm in a randomized complete block design replicated three times. Leaf blast severity data was scored based on a SES scale from IRRI. Further phenotypic characterization of these rice germplasm was done by collecting agronomic and yield data namely plant height, productive tillers, SPAD, days to anthesis, days to heading, days to maturity, filled grains,1000 grain weight, panicle length, grain length and grain yield. The data collected was subjected to analysis of variance using the PROC ANOVA procedure of Genstat program 15th Edition. The genotype means were separated using the Fisher's protected least significant differences (LSD) test at 5% significance level. To determine combining ability, data of each trait was analyzed using SAS (Version 9.3) program. Rice genotypes were significantly different for all the agronomic and yield traits except SPAD, filled grains and thousand grain weight. The parents, Nerica 4, Nerica 1, Mwur 4 and hybrids generated from a cross between Nerica 4 and Mwur 4, Nerica 1 and Kuchum and Nerica 1 and Komboka showed significantly shorter duration to flowering. The maturity period varied greatly with Nerica 4, Nerica 1 and Mwur 4 maturing early while BW 196 and BS 370 were late. Significant higher plant height was recorded in Duorodo. Similarly, BW 196 and a hybrid cross generated between Nerica 1 and Kuchum produced significantly higher number of productive tillers. From this study, Mwur 4 and Nerica 1 recorded significantly higher grain yield. Correlation analysis revealed that genotypes with a high number of filled grains, thousand seed weight, longer panicle length and longer grain length had high yield while those with few panicles per plant had lower yield. The parents, Nerica 4, Duorodo and hybrids generated from a cross between Nerica 4 and mwur 4 and Nerica 1 and mwur 4 combined low leaf blast severity and early flowering. The study revealed that the mean square GCA (m) were significantly different for all traits except SPAD while for GCA (f) significant differences were recorded in all traits except productive tillers, panicles per plant and thousand grain weight. SCA showed significant differences for all traits measured. Further analysis using General Predictability Ratio revealed that agronomic and yield traits were governed by non-additive genes. The parents, Komboka, Mwur 4 and Nerica 4 were good general combiners for grain yield, filled grains and had shorter duration to flowering. The hybrids generated from a cross between Mwur 4 and Nerica 4 and Komboka and Nerica 4 were the best crosses for grain yield, filled grains and had minimum days to 50% days to flowering. No single parent or specific cross contained all desirable traits hence to develop a high yielding genotype, a combination of desirable traits may be introgressed into adapted rice genotypes. The three parents with good general combining ability for

grain yield could be used in a hybridization program to introgress yield traits into adapted low yielding lines. The two best specific combiners could be exploited for heterosis breeding. The genotypes should be further screened under different environments for several seasons to conclusively determine resistance to prevalent races of the blast pathogen.

CHAPTER ONE

INTRODUCTION

1.1 Background information

Rice (*Oryza sativa* L.) contributes substantially to the total cereal grain production in the world (Mati *et al*., 2011). Globally, it is cultivated on approximately 150 million hectares, with production of 500 million metric tons annually. This represents 29% of the total grain output (Onyango, 2014). In Kenya, it is ranked third after maize and wheat and its rate of consumption is about 12% per annum. The current local production is 130,000 metric tons while consumption is 540,000 metric tons year^{-1}. This gap has to be met through importation valued at Ksh 7 billion (MoA, 2014).

The low production of rice is attributed to abiotic and biotic stresses, poor grain quality and lack of new improved and adapted varieties. The abiotic stresses are drought, cold, salinity, acidity and iron toxicity while the biotic factors include pests, weeds and diseases. Pests such as rice gall midge cause great losses in the field (Onyango, 2014). Weeds like striga species and false finger millet compete with rice for nutrients, water, and light thus interfering with its growth. They also harbor pests and produce root exudates that affect photosynthesis thus reducing yield (Dzomeku *et al*., 2007). Johnson (1996) revealed that yield loss in fields range between 20 - 100% depending on weeds control levels by farmers. In addition, rice is attacked by several viral, fungal and bacterial diseases which damage various parts of the crop (Webster & Gunnell, 1992; Jabeen *et al.*, 2012). Researchers have revealed that the major diseases are rice blast, brown spot, bacterial leaf blight and leaf streak, sheath blight, sheath rot, *Fusarium* wilt, stem rot, Tungro virus and false smut (Sharma & Bambawale, 2008).

Globally, rice blast is the most destructive disease caused by fungus known *Pyricularia oryzae* (Koultroubas *et al*., 2009). It has been estimated to destroy rice resulting in economic losses of over $70 billion (Scheuermann *et al*., 2012). The fungus occurs in 85 countries worldwide (Scardaci *et al., 2003)*. Africa is among the regions most affected where almost 40% of the rice consumed is imported (Seck *et al*., 2012). In Kenya, a heavy outbreak of rice blast was reported in 2007 and over the last six years there has been a reduction of 26.6% in production.

1.2 Problem statement and justification

Rice production in Kenya is very low ranging from 1to 4 tons/ha depending on farmers management level. Growing of poorly adapted rice varieties with undesirable traits is one of the major factors limiting production. Irrigated rice, mainly Basmati370, Basmati217 and BW196 is grown in central province, which is a major producer (MoA, 2009; Rosemary *et al*., 2010). These varieties are susceptible to diseases, have undesirable traits for consumer acceptability and are poorly adapted to the prevailing low soil fertility settings (Kimani, 2010). The demand for high productive upland varieties led to development of NERICA varieties which are high yielding. However, the NERICA varieties lack the local germplasm genes therefore have not been widely accepted by farmers (Kimani, 2010). Furthermore, the blast menace has continued to threaten rice production thus threatening national food and nutritional security. On an estimate, it annually destroys rice, which can feed around 60 million people (Scheuermann *et al*., 2012). The yield loss in susceptible varieties is 10-20% but this may rise to 80% (Koutroubas *et al*., 2009). In Kenya, a heavy outbreak of rice blast occurred in 2007 which destroyed 5,600 hectares (13,840 acres) of rice in Central Province (UN office for Coordination of Humanitarian Affairs, 2008). The pathogen of this disease mostly causes damage at the vegetative and reproductive stage causing leaf and panicle blast respectively. Leaf blast lesions are known to reduce the photosynthetic area of leaves. Neck blast disorganizes the tissues and is the most destructive (Zhu *et al*., 2005). Early attack results in partially filled or unfilled grains while a later attack leads to incomplete grain development (Seebold *et al.*, 2004). The disease occurrence is favored by persistent and prolonged dew periods and cool temperature in day time (Liu *et al*., 2004).

The disease has been managed through various strategies like use of resistant varieties, cultural practices and treatment with fungicides (Ribot *et al*., 2008). Cultural practices are low-cost measures and include burning disease straw, splitting nitrogen fertilizer and water management. However, where the environment is favorable for blast, these practices are rarely efficient. Chemical management has been used effectively in India, Japan and Philippine to reduce rice blast incidence and severity (Kumbhar, 2005). In Kenya, the few registered fungicides to control rice blast are very expensive, un-friendly to the environment and result in the development of resistance to pathogen. The most effective way for resource-poor farmers is growing of resistant cultivars (Sharma *et al.*, 2012). However, the available resistant varieties have undesirable traits for consumer acceptability. Rice improvement through breeding offers a sustainable solution. Through breeding, desired traits such as higher yield and disease resistance can be introduced to the adapted varieties. This will improve rice productivity, reduce rice import bills, provide additional income to the poor and result to sustainable management of the disease (Seck *et al*., 2012).

1.3 Objectives

1.3.1 The Broad objective

The overall goal of this project was to contribute to improved rice productivity through development of lines resistant to rice blast.

The specific objectives were:

1. To assess the performance of rice genotypes with regard to agronomic and yield related traits
2. To determine combining ability and heritability for agronomic and yield traits among rice genotypes

1.4 Hypotheses

1. There are no desirable traits among the rice germplasm.
2. Agronomic and yield traits are controlled by both additive and non-additive genes and show high heritability

CHAPTER TWO

LITERATURE REVIEW

2.1 The species of cultivated rice

Rice belongs to the genus *oryza*. *Oryza* has 22 species among which *Oryza glaberrima* (African rice) and *Oryza sativa* (Asian rice) are cultivated and others are wild (Linares, 2002). *Oryza glaberrima* has undergone improvement for over 3500 years for hardiness and drought resistance but is low yielding and prone to lodging and also losing yield through grain shattering before harvest. However, *Oryza sativa* has high yields but is susceptible to stresses of African ecologies like disease, pests, drought or soil problems (Jones, 2008). The survival to date of *O. glaberrima* has majorly been attributed to the fact that it is more tolerant and/or resistant to most stresses found in the African continent (Linares, 2002). Research has shown that the progenitors of the now globally cultivated *O. sativa* are two Asian species *Oryza rufipogon* and *Oryza nivara* (Vaughan *et al.*, 2003).

2.2 Rice production in the world

Rice is native to Asia but it has been traded and exported all over the world. Currently, China is the world leading paddy producer with a production volume of over 210 million metric tons (FAO, 2017). The United States was also ranked among the leading five rice exporters worldwide, primarily shipping this commodity to Mexico, Japan and Haiti. Other major rice exporting nations included India, Thailand, and Vietnam with around 10.3, 10 and 5.8 million metric tons, respectively (FAO, 2017). Africa produces 9% of the world's total and among the significant producers are Egypt, Nigeria, Cote d’Ivoire and Mali (FAO, 2005). Monem (2005) reported that in East Africa, the significant producers were Tanzania, Uganda and Kenya.

2.3 Rice production in Kenya

The crop has been ranked third and the main growers are small scale farmers (Mati, 2009; MoA, 2009). It has been estimated that Government irrigation schemes produce about 80% of the rice in which Mwea irrigation scheme produces more than 60% and only 20% is produced under rain-fed conditions (MoA, 2009). Rice is currently produced in four national schemes which cover the following areas: Mwea in central Kenya (9000 ha), West Kano and Ahero (3520 ha) and Bunyala (516 ha) which totals to approximately 13000 ha (MoA, 2010). West Kano, Ahero and Bunyala are located in western Kenya. According to National Irrigation Board data between 2005 and 2010, Mwea produces 88% of rice and gross value of 98% of output. The rice varieties grown are Basmati 370, IR2793-80-1, ITA310 and BW196. It has been estimated that 10-18kg of rice is consumed per capita per year (MOA, 2010). However, there is 12% increase in rate of consumption per annum. This has been attributed to better incomes, changes in eating habits, urbanization and as a result the demand for rice is expected to be high in the future (MOA, 2009). However, rice production has remained generally low; the current local production is 130,000 metric tons while consumption is 540,000 metric tons year^{-1}. This gap has to be met through importation valued at Ksh 7 billion (MoA, 2014). Rice production is constrained by both abiotic and biotic stresses which adversely affect the crop and causes very extensive losses to the yield of rice. The abiotic stresses are drought, cold, salinity, acidity and iron toxicity while the biotic factors include pests, weeds and diseases (Onyango, 2014).

2.4 Causal agent, symptoms, disease cycle and favorable factors for rice blast development.

Rice blast is caused by a fungus known as *Pyricularia oryzae (*Cavara). Other synonyms are *Magnaporthe grisea* (Hebert) Barr, *Pyricularia grisea* (Cook) Sacc.) (Couch and Kohn, 2002; Zhou *et al*., 2007). The fungus mostly causes damage at the vegetative and reproductive stage causing leaf and panicle blast respectively (Seebold *et al.*, 2004). The blast lesions found on leaves reduce photosynthesis. The lesions are spindle shaped and appear gray-green with brown border. Panicle blast is characterized by necrotic lesions which are dark and covers partially or completely around the node. The panicles formed are either partially filled or unfilled grains (IRRI, 2014).

The fungus reproduces both sexually and asexually. The asexual life cycle begins when the asexual spores called conidia lands on compatible host. These spores germinate to form a germ tube under optimal humidity. The nucleus in the cell undergoes mitotic division to give rise to a germ tube. One daughter nucleus stays in conidia cell while the other ends up developing appressorium which penetrates the leaf cuticle by generating large turgor pressure (up to 8 MPa). When the leaf is repeatedly colonized, the fungus sporulates on the leaf lesions thus spreading to new plants. Sexual stage of the fungus occurs when a perithecium is produced as a result of mating between two opposite strains. Ascospores are formed and when released they form appressoria which penetrates the cell (Dean *et al.* 2005). A single cycle occurs within 7-10 days if environmental condition are favourable. The lesions formed produce thousands of spores which results in several disease cycle (Guochang and Shuyuan, 2001).

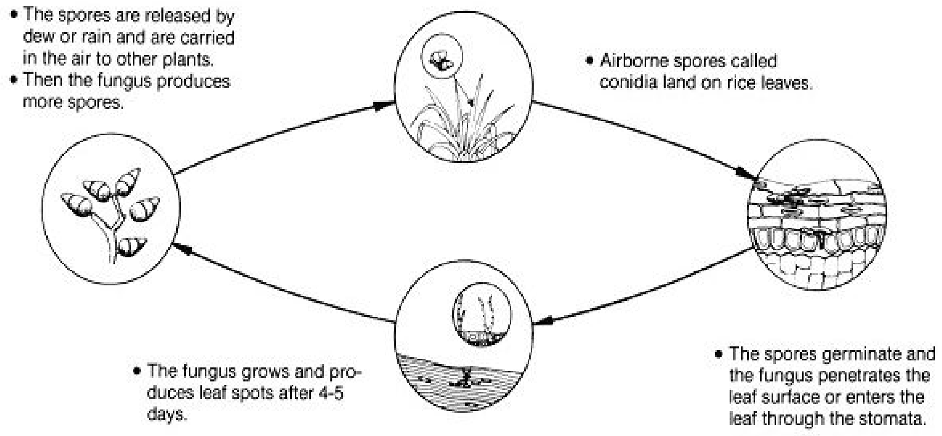

Figure 2. 1: Rice blast life cycle,Source: Webster and Gunnell,1992)

Blast can occur both in lowland and upland rice. The disease is favored by long periods of leaf wetness, a high amount of nitrogen and cool temperature of 22-25^{0}C (Fukuda *et al.*, 2004; Liu *et al.*, 2004). The severity of leaf blast epidemics is dependent on the genotype of rice planted, diversity and interaction of pathogen present and the infection and sporulation phases of the disease cycle. Several researchers have reported the genetic diversity of the rice blast fungus (Mian *et al*., 2003; Yang *et al.*, 2011). The life cycle of the pathogen is influenced by temperature. Researchers have revealed that the minimum temperature for mycelia growth of *P. grisea* is 80 – 90^{0}C, the optimum temperature is 25 to 30^{0}C and thermal death point is 51 – 52^{0}C (Arunkumar and Singh, 1995; Yang *et al.*, 2011). Other factors include physical and micro-climatic factors such as spore transport, deposition, infection and sporulation.

2.5 Approaches to management of rice blast

The disease has been managed through various strategies like planting of resistant varieties, cultural practices and spraying with appropriate fungicides.

2.5.1 Cultural practices

Cultural practices involve all the activities carried out on the farm before, during and after planting of rice. Blast incidence was reported to increase in the field when nitrogen supply was increased (Séré *et al*., 2011). To reduce the disease intensity, split applications of nitrogen based fertilizers are recommended.

Longer duration of leaf wetness appeared to increase neck blast damage (Séré *et al*., 2011). To reduce neck blast, rice is planted such that the reproductive stage falls at a time when the relative humidity is low.

Various studies have shown that application of silicon fertilizers such as calcium silicate to si-deficient soils reduces incidence and severity of blast. Seebold, *et al.* (2001) noted a reduction in sporulating lesions on partially resistant and susceptible rice cultivars fertilized with calcium silicate. Similarly Prabhu, *et al.* (2001) found that rice cultivar that accumulated more silicon on the shoots showed less incidence of rice blast. Cheap sources of silicon like rice straws of genotypes with high silicon content can be used to make this approach economically viable.

Burning of diseased straw and stubble is important because they are sources of inoculum and thus reduce inoculum load. It has also been shown that planting in water creates anaerobic condition that is unfavorable to the pathogen thus eliminates disease transmission (Koutroubas and Ntanos, 2003).

2.5.2 Chemical management

Several fungicides have been identified to control blast. For example Haq *et al.*, (2002) reported that Captan and Acrobat were the best fungicides in an experiment conducted under laboratory condition. Mancozeb was reported to control rice blast at 1000 and 10,000 ppm (Jamal-u-Ddin *et al*., 2012). Similarly, Gohel *et al*. (2008) revealed that mancozeb and other fungicides like Tricyclazole and Carbendaz controlled rice blast.Tirmali and Patil, (2000) evaluated 5 new fungicide formulation and they found out that Opus 15.5 SC reduce neck blast by 29.23%. Similarly, Varma and Santhakumari (2012) reported that foliar spraying Isoprothiolane at 1.5 ml/l significantly decreased the disease incidence (78.3%) and intensity (89.7%), this was followed by carpropamid disease incidence (67.5%) and intensity (80.5%) and carbendazim disease incidence (56.9) and intensity (73.1%) over the control. The highest grain and straw yield increase compared to control was also recorded with isoprothiolane (22.5 and 28.3%), followed by carpropamid (20.5 and 25.7%).

2.5.3 Use of resistant varieties

Rice breeders use vertical and horizontal resistance to develop varieties. The vertical resistance is controlled by few major genes and has long been used by breeders to develop varieties. However, it is not durable (Chen *et al*., 2004; Liu *et al*., 2002). Research has shown that there are 70 and above *Pi* genes (Dai *et al*., 2007; Lin *et al*., 2007). The other type is horizontal resistance; it is stable, durable and polygenic. Unfortunately, it is of low heritability since the environment influences the expression of the resistance genes (Suh *et al*., 2009). Research has shown that *Pi40* which is a major gene (Suh *et al*., 2009) and *pi21* which is recessive (Fukuoka and Okuno, 2001) confer durable resistance. In addition, gene pyramiding of several vertical resistance genes has been shown to confer durable blast resistance (Hittalmani *et al*., 2000). Planting multi-lines also reduces the disease pressure by ensuring stability of blast control (Zhu *et al*., 2000). Varieties like IR64, IR6203 and OM1570 are considered to possess durable resistance (Sere *et al*., 2011).

2.6 Breeding for resistance to rice blast

Rice breeders have used various methods to breed for rice blast namely pedigree, backcross, recurrent selection and single seed descent (Singh *et al.*, 2000). The pedigree method entails record keeping of the origin of selected lines. The method has been used in AfricaRice to select resistant plants (Singh *et al.*, 2000).Backcrossing is widely used in rice breeding to incorporate a specific trait to an adapted cultivar while maintaining the desirable qualities like adaptation and productivity (Poehmann, 2006). The method has been used in the South and Southeast Asia to improve varieties like KDML105 for their resistances to blast (Toojinda *et al*., 2005). Recurrent selection has also been used in rice breeding and its benefits are mainly shorter breeding cycle which allows more precise follow-up of genetic gains. This method was used to develop cultivar CG-91 with resistance to rice blast (Correa *et al*., 2000). Single-seed descent involves advancing one seed per plant till the F_6 generation. As currently practiced, single seed descent is utilized to reduce the time required to grow the segregating generations because only one seed is harvested from each plant (Poehmann, 2006). Using this method, Pasha *et al*., (2013) evaluated rice genotypes for resistance to rice blast.

2.7 Mating designs used in rice

Mating designs are important in estimating genetic variance (Khan *et al*., 2009). There are six mating designs used in rice namely: Bi-parental, Polycross, Top cross, Line x tester design, Diallel and North Carolina. Bi-parental mating design is the simplest design that produces families which are both half and full sib. However, the design doesn’t provide all the information needed by the model to estimate all the parameters (Acquaah, 2012).

Polycross is the pollination by natural crossing a group of cultivars which are grown in isolated blocks to encourage random open pollination. A practical application is in the production of synthetic varieties (Acquaah, 2012). Top cross design is the pollination between a line or clone and a common pollen parent. Selection is done and then crossing with a tester parent of narrow- or broad-based heritability (Aly *et al*., 2011). Line x tester design is where more than ones tester is used (Sharma, 2006). It is simple and gives both full-sibs and half-sibs. The design gives SCA for each cross and provides GCA of lines and testers (Sharma, 2006).

A complete diallel mating design has both selfs and reciprocals (Schlegel, 2010). Random and fixed models are used for analysis (Griffing, 1956b). A random model is where the parents randomly mate and it estimates both GCA and SCA variances. Fixed model is where parents are fixed and it estimates SCA for each pair of parents and the GCA for each parent (Acquaah, 2012).

North Carolina mating design I**,** II and III were defined by Comstock and Robinson in 1952. The three designs have an advantage over full diallel in that information on combining ability can be obtained easily. North Carolina design 1 is where each male is crossed to different female; it is the least powerful design. North Carolina Design II is where each male parent is crossed to the same females. The design gives GCA, SCA and heritability (Acquaah, 2012).

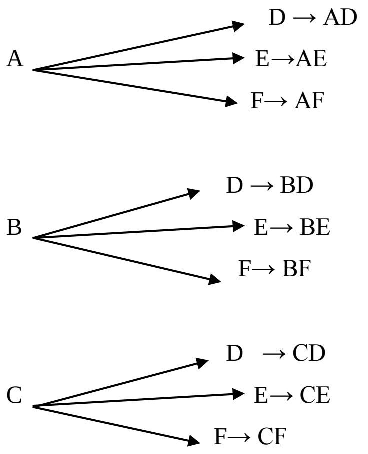

Figure 2. 2: NCD II mating design, source: Acquaah, 2012

Table 2. 1: ANOVA table for a NCD II mating design in a single location

Source of variation	Df	Ms	Expected mean squares
Replications (r)	r-1		
Males (m)	m-1	m1	σ^2 w+r σ^2 mf + rfσ^2 m
Females (f)	f-1	m2	σ^2 w+r σ^2 mf + rf σ^2 f
Females × Males	(m-1) (f-1)	m3	σ^2 w+r σ^2 mf
Within progenies	mf (r-1)	m4	σ^2 w
Error	(r-1) (mf-1)	m5	
Total	rmf-1		

NCD II-North Carolina Mating Design II, ANOVA-Analysis of Variance for single location, Source: Kearsey and Pooni (1996)

2.8 Mode of gene action conferring resistance in rice

The analysis of the parents and crosses gives information on additive and dominance genetic variance which are useful for selection of parents and crosses for eventual success (Kalita and upadhya, 2000). General Combining Ability measures additive gene effects while Specific Combining Ability measures non-additive gene effects (Pradhan and singh, 2008). The higher magnitude of dominance variances shows that non-additive gene action is predominant to the additive one (Sharifi, 2012). Previous studies have reported the predominance of non-additive gene action for length of panicle, number of spikelets, filled grains and grain yield per plant, while additive component was found predominant for days to flowering, number of tillers per plant, number of panicles plant and thousand grain weight (Bansal *et al.*, 2000). Panwar (2005) reported that additive gene action was high for seedling height, panicles per plant, grain length, breadth ratio, spikelets per panicle while non-additive gene action was high for plant height, days to 50% flowering, days to 80% maturity, 1000-grain weight and grain yield per plant. An 8 x 8 diallel crossing study showed that additive genes were predominant for plant height, panicle length, panicle per plant and primary branches panicle, however, panicle fertility, days to maturity and paddy yield expressed non-additive effects (Mehmood *et al*., 2002). Kumar *et al*. (2008) reported that non-additive gene action was high for days to 50% flowering, plant height, grain yield and days to maturity.

2.9 Heritability in rice

Heritability is the proportion of phenotypic variance attributable to genetic variance. It is divided into broad-sense and narrow-sense (Dabholkar, 1992). Gene action plays an important role in determining heritability in that traits controlled by additive gene effects tend to have higher heritability values than traits controlled by non-additive gene effects (Dabholkar, 1992). Combining ability is important because it gives additive genetic variance which is important for estimating narrow sense heritability (Griffing, 1956). Ali *et al*. (2000) reported significant broad sense heritability for some yield and yield components except for number of tillers per plant and panicle length. Heritability estimates were reported to be maximum for plant height, 100-seed weight and number of tillers per plant. Singh *et al*. (2005) reported high heritability for plant height, days to maturity and grain yield and they suggested selection based on these traits. Agrawal (2003) conducted an experiment involving seven parental lines and 21 F_2 populations in rice and reported high heritability for the number of grains per panicle, yield per plant, days to flowering, days to maturity and number of tillers per plant. Kimani (2010) reported high broad sense heritability for days to heading, days to anthesis and days to maturity.

CHAPTER THREE

PERFORMANCE OF RICE GENOTYPES IN AGRONOMIC AND YIELD TRAITS

3.1 Abstract

The demand for rice in Kenya is high while production has remained far below consumption demand for quite a number of years. Growing of poorly adapted varieties with undesirable traits is one of the major factors limiting production. The objective of this study was to determine the performance of rice cultivars for agronomic and yield traits. Seven genotypes were pollinated in North Carolina II mating design to generate F_1 hybrids. The 12 F_2 and F_3, 7 parents and 1 check variety made a total of 20 entries which were planted at Kenya Agricultural and Livestock Research Organization-Mwea on 27th September, 2016 and 7th July, 2017. Each genotype was planted in a plot size of 3 × 3 m, at inter-row spacing of 20 cm and intra spacing of 15 cm in a randomized complete block design replicated three times. Leaf blast severity data was scored based on a SES scale from IRRI. Further phenotypic characterization of these rice germplasm was done by collecting agronomic and yield data namely plant height, productive tillers, SPAD, days to anthesis, days to heading, days to maturity, filled grains, 1000 grain weight, panicle length, grain length and grain yield. The data collected were subjected to analysis of variance using the PROC ANOVA procedure of Genstat program 15th Edition. The genotype means were separated using the Fisher's protected least significant differences (LSD) test at 5% significance level. Rice genotypes were significantly different for all agronomic and yield traits. The parents, Nerica 4, Nerica 1, Mwur 4 and hybrids generated from a cross between Nerica 4 and Mwur 4, Nerica 1 and Kuchum and Nerica

1 and Komboka showed significantly shorter duration to flowering. The maturity period varied greatly with Nerica 4, Nerica 1 and Mwur 4 maturing early while BW 196 and BS 370 were late maturing. Significantly higher plant height was recorded in Duorodo than in BW 196. Similarly, BW 196 and a hybrid cross generated between Nerica 1 and Kuchum produced significantly higher number of productive tillers than Nerica 4. From this study, Mwur 4 and Nerica 1 recorded significantly higher grain yield than BS 370. Correlation analysis revealed that genotypes with a high number of filled grains, 1000 seed weight, long panicles and long grains had high yield while those with few panicles per plant had lower yield. The parents, Nerica 4, Duorodo and hybrids generated from a cross between Nerica 4 and Mwur 4 and Nerica 1 and Mwur 4 combined low leaf blast severity and early flowering. No single parent or specific crosses showed good combination of all traits. Hence to develop a high yielding genotype, a combination of desirable traits may be introgressed into adapted rice genotypes. The genotypes should be further screened under different environments for several seasons to conclusively determine resistance to prevalent races of the blast pathogen.

3.2 Introduction

Rice contributes significantly to food security. Nutritionally, it is a source of carbohydrates, proteins and contributes 20% of world energy (Ahsan *et al*., 2013; Ali *et al*., 2012). In Kenya, the demand for rice, particularly in urban areas, has increased rapidly compared to other cereal crops (Mati et al., 2011). Currently, local production is 130,000 metric tons while consumption is 540,000 metric tons year^{-1}. This huge gap has to be met through importation valued at Ksh 7 billion (MoA, 2014). Importation of rice from the world market is very expensive, risky and unsustainable strategy which eventually leads to food insecurity. This calls for development of high yielding rice varieties which are cheap and have desirable traits for consumer acceptability and thus can compete with imported rice.

Increasing rice production can be achieved by addressing constraints affecting production which include diseases like rice blast, lack of access to quality seeds, abiotic stresses such as drought, late maturity and poor adaptability of new varieties. These constraints raise the cost of production thus limiting the participation of rice farmers in the domestic and international market thus impacting negatively on the growth of rice sub- sector (Onyango, 2014).

Growing of poorly adapted varieties with undesirable traits is one of the major factors limiting production. Rice farmers in western Kenya have been producing Duorodo while lowland varieties have been grown mainly in coastal region whereby some have been lost. Irrigated rice mainly Basmati 370, Basmati 217, ITA310, IR2793-80-1 and BW196 is grown in Kirinyaga County, which is a major producer (MoA, 2009; Rosemary *et al*., 2010). These varieties are susceptible to diseases, have undesirable traits for consumer acceptability and are poorly adapted to the prevailing low soil fertility settings (Kimani, 2010). The demand for high productive upland varieties has led to development of NERICA varieties which are high yielding. However, the NERICA varieties lack the local germplasm genes and have not been widely accepted by farmers (Kimani, 2010). Furthermore, the most devastating fungal disease attacking these varieties is rice blast responsible for 10-20% yield loss in susceptible varieties but this may rise to 80% (Koultroubas *et al*., 2009). Management of rice blast could be achieved through various strategies like use of resistant varieties, cultural practices and treatment with fungicides (Ribot *et al*., 2008). Cultural practices are low-cost measures and include burning disease straw, splitting nitrogen fertilizer and water management. However, where the environment is favorable for blast, these practices are rarely efficient. Mitigation by use of chemicals either by spraying or seed dressing is costly and detrimental to the environment (Kumbhar, 2005). Given the current production constraint, rice improvement through breeding offers a sustainable solution. Through breeding, desired traits such as higher yield and disease resistance can be introduced to the adapted varieties. Therefore; this present study was carried out with the objective of determining the performance of rice cultivars with regard to the agronomic and yield traits.

3.3 Materials and methods

3.3.1 Experimental site

Kenya Agricultural and Livestock Research Organization (KALRO) - Industrial Crops Research Centre (ICRC) Mwea-Tebere (Formally National Rice and Fiber Research Centre) is located in Mwea Division, Kirinyaga County, Kenya (Kimani, 2010). The Centre is 24 km South West of Embu town and about 112 km North East of Nairobi. It lies on Latitude 00° 37’ S and Longitude 37 ° 20’ E at an elevation of 1159 m above sea level (MASL). The average rainfall is about 850 mm with a range of 500 - 1250 mm divided into long rains (March – June with an average of 450 mm) and short rains (Mid-October to December with an average of 350 mm). The rainfall is characterized by uneven distribution in total amounts, time and space. The temperature ranges from 15.6 ° C to 28.6° C with a mean of about 22° C. The soil is nitosol, which is deep, well drained dusky-red to dark reddish-brown, friable clay with low fertility (Jaetzold and Schmidt, 1983).

3.3.2 Rice germplasm used for evaluation

The rice genotypes used for evaluation were 7 parents, 12 hybrids and 1 check variety (Table 3.1).

Table 3. 1: Characteristics of genotypes used for evaluation in KALRO-Mwea

Genotype	Origin	Characteristics
BS 370	Kenya	Aroma, very good cooking quality, susceptible to blast
BW196 (check)	Kenya	Resistant to blast, high yielding
DUORODO	Kenya	Good grain quality, resistant to blast
KOMBOKA	Tanzania	Moderate aroma, high yielding, susceptible to blast
KUCHUM	Nagoya university Japan	Very good cooking quality, susceptible to blast
MWUR 4	Kenya	High yielding, tall , resistant to blast
NERICA 1	Africa Rice centre	High yielding, aroma, tall , resistant to blast
NERICA 4	Africa Rice centre	High yielding, taller , resistant to blast, hard to thresh
DUO×BS 370	Kenya	Susceptible to blast
DUO×KOMB	Kenya	Susceptible to blast
DUO×KUCHM	Kenya	Susceptible to blast
DUO×MWU 4	Kenya	Resistant to blast
NER 1×BS 370	Kenya	Good grain quality
NER 1×KOMB	Kenya	Resistant to blast
NER1×KUCHM	Kenya	High yielding
NER 1×MWU 4	Kenya	High yielding, resistant to blast
NER 4×BS 370	Kenya	High yielding, susceptible to blast
NER 4×KOMB	Kenya	High yielding
NER 4×KUCHM	Kenya	Susceptible to blast
NER 4×MWU 4	Kenya	High yielding, Resistant to blast

KALRO- Kenya Agricultural and Livestock Research Organization. Genotypes evaluated in two seasons

3.3.3 Evaluation of genotypes for rice blast severity, agronomic and yield traits

The 12 F_2 and F_3 and 8 parents made a total of 20 entries, were planted at KALRO-Mwea on 27th September, 2016 and 7th July, 2017. Each genotype was planted in a plot size of 3 × 3 m, at inter-row spacing of 20 cm and intra spacing of 15 cm in a randomized complete block design replicated three times. A path of one metre was left between replicates for easy movement during data collection. Three seeds per hill were sown and later thinned to one plant per hill. A susceptible local variety namely Basmati 370 was planted as a spreader around the experimental plots. DAP fertilizers was applied at planting at a recommended rate of 60 kg P ha^{-1} and top dressed with CAN at 120 kg N ha^{-1} at 14 days after seeding. Normal cultural practices such as weeding were carried out manually. Data was collected on agronomic and yield traits, plant height, productive tillers, chlorophyll content, days to anthesis, days to heading, days to maturity, filled grains,1000 grain weight, panicle length, grain length and grain yield. Leaf blast severity data was scored based on a SES scale from IRRI (IRRI, 2014).

3.3.4 Inoculum preparation and inoculation method

To ensure infection, the nursery was inoculated using diseased plant debris and artificial inoculation. Inoculums for *Pyricularia oryzae* was obtained from infected plant debris. They debris were cut and chopped into small pieces. The chopped leaves were spread over the entries of the nursery when the seedlings were 21 days old. The nursery was irrigated with sprinklers everyday to maintain the humidity thus facilitate disease development. Normal agronomic practices were followed *(*Khan *et al*., 2001). Artificial inoculation was done two weeks after the first inoculation. Diseased leaves were cut into small pieces around the area showing the blast lesion then surface sterilized with 1% sodium hypochlorite for 1 minute followed by 3 washes with sterile distilled water. Solutions of PDA were poured on the Petri dishes in the laminar flow cabinet. The plant pieces were placed in Petri dishes sealed with a tape to avoid contamination. They were incubated at 25 ^{0}C for 24 h to encourage sporulation. After incubation, these infected leaf pieces were examined under stereo dissecting microscope. Abundant pathogen growth and sporulation were observed around the lesions with grey, dense and bushy appearance. A sterile moistened needle was used to pick out some conidia by brushing the needle across the sporulating lesion. The conidia were placed on potato dextrose agar media plates containing streptomycin (WARDA, 2004). Plates were incubated at 25°C for 7 days with 12h darkness and 12h light. The identity of *P. oryzae* was verified by checking the conidia under light microscope (WARDA, 2004). Identification of the pathogen on PDA is greyish, mycelium is septate and branched. Conidiophores arise singly, rarely branched and slightly thickened at the base. Conidia are usually 2-septate, apex narrow and base rounded (Agrawal *et al*., 1989; Mew and Gonzales, 2002). Following 24h incubation at 25^{0}C, germinating conidia were picked up and sub cultured onto a potato dextrose agar media plates amended with streptomycin using a fine scalpel. An aqueous suspension of 1×10^6 spores/ml of the isolate of *Pyricularia oryzae* was prepared. The seedlings were inoculated with aqueous suspension of 1×10^6 spores/ml of the isolate of *Pyricularia oryzae* as they reached heading stage *(*Khan *et al*., 2001). After the inoculation, water was applied by a sprinkler to the leaves three times every day to facilitate disease development.

3.3.5 Assessment of agronomic and yield parameters

Days to heading and anthesis were measured by counting days from planting to when 50% of plants in a plot and 50% of tillers per plant had panicle exerted 2/3 way and flowered and shed pollen respectively. Total chlorophyll content of ten randomly plants was recorded at heading stage using SPAD. Days to maturity was measured by counting the number of days from planting to when 80% of grains in the plot were mature. Plant height of ten random plants per replicate was measured in centimeters from the base of the main tiller to the tip of the panicle at maturity. Productive tillers of ten randomly plants per replicate were counted at maturity. A total of seven yield and yield contributing characters, designated as growth characters were recorded. Grains per panicle of ten randomly selected plants per replicate were weighed at harvest. One thousand well- developed whole grains of each genotype were measured in grams at harvest. They were dried to 13% moisture content and then weighed on a precision balance. Total number of panicles in a plant was counted for ten randomly selected hills at time of maturity. Total number of filled grains per panicle was counted from ten randomly selected panicles at maturity. The grain length of each ten sampled grain per plot was measured at harvest using a micrometer. Grain yield were weighed on plot basis.

3.3.6 Assessment of rice blast incidence and severity

Blast assessment was performed on individual plant basis. The assessment started 30 days after seeding and continued for six observations at seven day interval for leaf blast. This was scored using standard evaluation system (SES) of 0-9 scale (Table 3.2).

Table 3. 2: Scale used for evaluation of rice blast severity in KALRO-Mwea

Scale	Lesion type
0	No lesions observed
1	Small brown specks of pin-point size or larger brown specks without sporulating center
2	Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin. Lesions are mostly found on the lower leaves
3	Lesion type is the same as in scale 2, but a significant number of lesions are on the upper leaves
4	Typical susceptible blast lesions2- 3 mm or longer, infecting less than 4% of the leaf area
5	Typical blast lesions infecting 4-10% of the leaf area
6	Typical blast lesions infecting 11-25% of the leaf area
7	Typical blast lesions infecting 26-50% of the leaf area
8	Typical blast lesions infecting 51-75% of the leaf area and many leaves are dead
9	More than 75% leaf area affected

Scale of 0-9 (IRRI, 2014)

The percentage disease incidence was measured as the percentage of the number of leaves showing the disease symptoms. Leaf blast severity data were converted to AUDPC according to the formula described by Shaner and Finney (1977).

$$\text{AUDPC}=\sum_{i=1}^{K} (X_{i+1}+X_i)/20(t_{i+1}-t_i)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{Equation 3.}$$

Where X_i = blast severity at the ith observation, t_i = time (days) at the ith observation, and k = total number of observations.

3.3.7 Data analysis

Analysis of variance for traits was done using GENSTAT 15th edition software. Mean comparison was done using the Fisher’s protected least significant differences (LSD) test at 5% significance level (Brigitte, 1999). Rice blast severity, agronomic and yield data were subjected to GENSTAT 15th Edition for correlation among the traits (Pearson, 1896).

3.4 Results

3.4.1 Agronomic and yield traits

Rice genotypes were significantly different at $P<0.05$ for all agronomic and yield traits except SPAD, filled grains and 1000 grain weight. Seasonal variations were significant for plant height and filled grains. Significant genotypes x season interactions were revealed only among the filled grains (Table 3.3).

3.4.2 Rice blast incidence and severity

Rice genotypes were significantly different at $P<0.05$ for rice blast incidence, Final score and AUDPC. Significant genotypes x season interactions were revealed only in rice blast incidence (Table 3.3).

Table 3. 3: Analysis of variance for rice blast severity, agronomic and yield traits for different rice genotypes during long and short rainy season in KALRO-ICRC Mwea

Source	Disease parameters				Agronomic traits						Yield traits					
of variation	DF	FS	DI	AUDPC	PH	PTL	SD	DH	DA	DM	FG	PP	TG	PL	GL	GY
Replication	2	0.5	102.2	292.1	108.8	23.8	209.1	107.5	119.0	11.1	16.4	1.9	18.4	5.1	0.4	5.2
Genotypes	19	16.5*	3500.4*	6377.5*	1092.9*	74.5*	105.0	1537.3*	1537.5*	1278.7*	175.9	53.9*	14.2	20.5*	4.2*	26.7*
Season	1	0.5	29.3	608.4	4165.4*	3.4	5.7	156.6	180.3	177.6	2766.7*	24.7	29.1	12.9	2.8	12.6
Genotypes x season	19	0.1	223.7*	50.8	118.8	7.7	39.3	166.3	170.7	0.5	2270.3*	9.1	9.8	4.9	0.6	0.7
Residual	78	0.3	26.5	225.9	125.0	8.1	46.3	65.6	67.5	61.3	173.2	6.7	5.2	2.5	0.6	2.7
Total	119															

*Significant at P ≤ 0.05, FS-final rice blast score, DI-Disease incidence, AUDPC-area under the disease progress curve, PH – Plant height, PTL- Productive tillers SD- SPAD, DH-days to heading, DA-days to anthesis, DM –days to maturity, FG-filled grains, PP-panicles per plant, TG - 1000 grain weight, PL-panicle length, GL-grain length, GY-grain yield (t/ha)

3.4.3 Performance of rice cultivars for agronomic and yield traits

Rice genotypes were significantly different for all agronomic and yield traits. Variations among parents for plant height were found. The highest plant height was recorded in Duorodo and lowest in BW 196. Similarly, BW 196 and Komboka produced significantly higher number of productive tillers than Nerica 4. The parents, Nerica 4, Nerica 1 and Mwur 4 showed significantly shorter duration to flowering while BW 196 and BS 370 had significantly longer periods to flowering. Parents, Nerica 1, Mwur 4 and BS 370 showed a significantly higher potential of producing panicles/plant but Kuchum produced significantly lower number of panicles/plant. Mwur 4, Nerica 4 and Nerica 1 recorded significantly higher grain yield than other parents. On the other hand, Duorado recorded significantly longer grain length while kuchum and BS 370 produced significantly longer panicle length than BW 196.

The hybrids generated from a cross between Nerica 4 and mwur 4, nerica 1 and kuchum and nerica 1 and komboka showed significantly shorter duration to flowering while the hybrids generated from a cross between duorodo and mwur 4 and Nerica 4 and BS 370 had significantly longer periods to flowering. Significantly higher plant height was recorded in a cross between Nerica 4 and Mwur 4 and the lowest in a cross between Nerica 4 and Kuchum. The cross between Nerica 1and Kuchum produced significantly higher number of productive tillers than the cross between Nerica 1 and Mwur 4. On the other hand, the hybrids generated from a cross between Duorodo and Komboka produced significantly longest panicle while a cross between Nerica 1 and BS 370 and Nerica 1 and

Komboka was due to high number of panicles/plant compared to other hybrids. (Table 3.4 and 3.5)

Table 3. 4: Agronomic and yield traits for different rice genotypes during 2016 short rainy season in KALRO-ICRC Mwea

	Agronomic traits						Yield traits					
Genotypes	PH	SD	PTL	DH	DA	DM	FG	TGW	PL	GL	PP	GY
BS 370	96.3	31.3	15.9	107.3	108.3	141.3	55.3	20.1	19.5	7.7	15.1	1.3
BW196 (check)	49.0	48.0	25.0	140.3	141.3	169.3	15.0	19.9	14.7	5.8	11.9	2.0
DUORODO	115.0	40.3	12.7	87.5	88.5	115.3	18.7	21.1	18.4	8.1	11.2	5.3
KOMBOKA	68.6	26.8	19.7	104.6	105.6	134.0	12.5	17.9	17.9	7.1	11.8	1.6
KUCHUM	105.6	38.1	10.4	87.0	87.9	120.3	18.9	15.0	20.8	7.4	9.8	3.4
MWUR 4	102.7	44.5	12.1	80.6	81.6	116.0	18.4	21.5	17.4	6.2	25.6	6.9
NERICA 1	96.0	43.8	10.0	77.5	78.5	116.7	23.6	20.1	18.0	6.5	16.7	6.0
NERICA 4	89.7	46.4	9.8	75.2	76.2	119.7	16.0	22.7	18.8	5.9	11.3	6.0
DUO×BS 370	83.2	34.2	8.6	95.5	99.9	137.3	45.9	19.4	16.2	5.1	12.1	1.8
DUO×KOMB	77.1	33.5	11.7	99.8	100.8	138.0	45.7	19.0	20.5	5.8	12.8	1.4
DUO×KUCHM	76.5	38.0	12.6	97.2	98.2	122.0	21.7	18.6	19.1	5.9	13.4	3.4
DUO×MWU 4	85.1	33.1	10.9	97.7	98.7	156.0	16.9	17.5	20.3	7.2	9.5	2.2
NER 1×BS 370	82.9	41.2	12.9	88.7	89.7	128.0	59.5	19.8	15.4	7.9	10.6	3.5
NER 1×KOMB	109.6	38.5	10.4	82.6	87.1	121.7	18.1	18.9	19.7	7.6	12.5	4.1
NER1×KUCHM	93.3	34.0	13.9	74.9	75.9	119.3	39.2	21.7	15.8	8.3	12.6	1.0
NER 1×MWU 4	76.2	33.2	6.7	97.8	98.8	120.7	49.9	19.6	10.9	5.2	11.9	2.5
NER 4×BS 370	95.5	30.5	12.9	104.2	105.2	139.7	49.3	18.7	18.9	7.5	10.9	1.8
NER 4×KOMB	97.1	46.5	13.2	86.1	83.6	121.3	16.9	19.2	16.5	7.4	15.8	7.8
NER 4×KUCHM	63.2	34.2	11.5	89.8	90.8	136.7	39.2	20.8	18.3	6.0	10.9	2.4
NER 4×MWU 4	111.1	39.0	12.7	74.7	75.7	114.7	21.2	18.7	19.7	7.5	12.4	6.2
Grand mean	88.7	37.8	12.7	92.5	93.6	129.4	30.1	19.5	17.8	6.8	12.9	3.4
LSD (5%)	20.1	12.3	5.5	14.2	14.5	13.0	14.1	4.5	2.2	1.1	4.0	2.7
CV (%)	7.0	9.7	6.8	3.1	3.2	0.4	9.4	6.4	1.5	1.4	1.1	8.8

PH - Plant height, SD- SPAD, PTL - Productive tillers, DH-days to heading, DM-days to anthesis, DM –days to maturity, FG-filled grains, TGW - Thousand grain weight, PL-panicle length, GL-grain length, PP-panicles per plant, GY-grain yield (t/ha)

Table 3. 5: Agronomic and yield traits for different rice genotypes during 2017 long rainy season in KALRO ICRC Mwea

	Agronomic parameters						Yield parameters					
Genotypes	PH	SD	PTL	DH	DA	DM	FG	TSW	PL	GL	PP	GY
BS 370	81.4	34.5	17.3	90.6	91.6	144.3	9.5	13.2	18.5	7.7	13.3	1.5
BW196 (check)	48.7	32.3	23.1	158.3	159.3	171.7	47.1	16.6	14.6	5.8	10.7	2.9
DUORODO	94.9	43.4	8.5	88.9	89.9	119.3	42.3	21.4	17.4	8.2	10.4	3.9
KOMBOKA	61.0	35.3	16.3	81.7	82.7	117.7	56.7	16.5	17.2	7.1	11.3	2.0
KUCHUM	79.8	39.5	10.2	86.9	87.9	121.7	57.9	17.3	18.2	7.4	9.1	3.4
MWUR 4	84.6	41.4	10.3	75.3	76.3	136	51.1	21.4	16.3	8.1	11.9	7.7
NERICA 1	84.2	43.9	11.9	77.5	78.5	118.3	55.5	19.3	18.0	7.3	22.7	6.8
NERICA 4	87.5	44.6	10.6	74.0	75.0	123.3	72.9	19.2	16.4	6.9	11.7	5.8
DUO×BS 370	75.8	37.4	12.0	86.4	87.7	139.0	14.2	16.2	18.9	6.7	13.9	2.0
DUO×KOMB	70.5	34.9	9.3	89.8	91.1	140.7	11.1	17.8	20.4	5.7	10.3	1.8
DUO×KUCHM	74.4	37.5	11.3	98.5	99.5	123.7	46.8	20.4	17.8	6.7	13.1	4.0
DUO×MWU 4	69.3	35.6	11.8	103.8	105.2	158.3	69.1	20.8	20.1	7.2	8.0	2.7
NER 1×BS 370	76.8	41.4	13.4	88.0	89.4	131.7	9.7	19.5	14.3	8.0	10.0	3.9
NER 1×KOMB	88.7	40.4	12.1	79.8	81.1	124.0	51.9	17.2	16.4	7.3	12.9	7.6
NER1×KUCHM	83.0	39.5	13.8	79.6	80.9	122.0	21.1	16.7	16.3	7.9	11.1	1.7
NER 1×MWU 4	67.9	38.2	9.9	87.6	88.9	123.7	5.9	19.5	14.3	5.2	11.2	3.0
NER 4×BS 370	82.7	33.0	13.9	95.2	96.2	142.3	8.2	16.8	17.6	7.3	12.1	2.1
NER 4×KOMB	82.1	38.6	10.5	84.0	86.0	123.3	72.9	21.7	16.5	7.4	14.3	8.3
NER 4×KUCHM	66.1	35.3	12.0	103.0	104.0	138.7	27.4	21.3	17.7	6.7	11.5	2.9
NER 4×MWU 4	78.5	37.3	8.8	74.5	75.8	117.0	62.5	18.0	17.1	7.5	11.3	6.6
Grand mean	76.9	38.2	12.4	90.2	91.2	131.8	39.7	18.5	17.2	7.1	12.0	4.0
LSD (5%)	13.1	9.9	3.6	12.5	12.5	13.2	26.9	2.6	3.0	1.4	4.5	2.8
CV (%)	4.4	2.5	8.6	1.1	1.1	0.4	8.5	2.4	2.7	2.1	4.5	13.1

PH - Plant height, SD- SPAD, PTL - Productive tillers, DH-days to heading, DM-days to anthesis, DM –days to maturity, FG-filled grains, TGW - Thousand grain weight, PL-panicle length, GL-grain length, PP-panicles per plant, GY-grain yield (t/ha)

3.4.4 Performance scores of rice cultivars for blast severity and incidence

Different genotypes varied significantly under rice blast artificial infection. The parents BW 196, Duorado and Nerica 4 showed the slowest disease progression. The three parents had also low final score and rice blast incidence. The hybrids generated from a cross between Duorado and Kuchum and Nerica 4 and Mwur 4 had low final score, rice blast incidence and low AUDPC values. Some other good hybrids with low %DI included a cross between Nerica 1and Mwur 4 and Duorado and Mwur 4 (Table 3.6 and 3.7).

Table 3. 6: Rice blast severity and incidence scores for different rice genotypes during 2016 short rainy season in KALRO- Mwea

Genotypes	Weeks after inoculation						
	1	2	3	4	5	%DI	AUDPC
BS 370	2.7	3.7	4.6	5.5	7.1	77.9	136.8
BW196	0.0	0.0	0.0	0.1	0.1	2.1	1.0
DUORODO	0.6	1.2	1.9	2.3	2.7	14.7	52.3
KOMBOKA	2.2	3.4	3.9	4.4	5.5	64.3	114.0
KUCHUM	1.2	1.9	2.2	2.6	3.1	17.9	65.2
MWUR 4	1.3	1.8	2.1	2.5	3.7	22.2	64.8
NERICA 1	1.3	2.1	2.4	2.7	3.1	15.6	68.4
NERICA 4	0.6	1.0	1.7	2.4	2.9	18.0	50.9
DUO×BS 370	2.6	3.4	4.1	4.7	6.0	62.6	120.6
DUO×KOMB	2.5	3.2	3.8	4.4	5.8	60.9	114.0
DUO×KUCHM	0.9	1.7	1.8	2.4	3.0	16.6	57.7
DUO×MWU 4	1.7	2.3	2.6	2.9	3.5	20.0	76.7
NER 1×BS 370	1.6	2.9	3.0	3.8	4.9	45.5	94.4
NER 1×KOMB	2.4	3.8	4.1	4.6	5.3	60.7	118.7
NER1×KUCHM	2.0	2.7	3.0	3.2	3.5	23.1	85.4
NER 1×MWU 4	1.7	2.3	2.6	3.1	3.4	18.8	76.9
NER 4×BS 370	2.5	3.8	4.5	5.2	6.8	70.5	132.8
NER 4×KOMB	1.5	2.5	2.8	3.1	3.7	27.8	80.1
NER 4×KUCHM	1.6	2.2	2.6	2.8	3.5	24.7	74.8
NER 4×MWU 4	1.6	2.1	2.3	2.6	3.0	17.4	68.2
Grand mean	1.6	2.4	2.8	3.3	4.0	34.1	82.7
LSD (5%)	1.0	1.0	1.1	0.9	0.9	11.3	26.3
CV (%)	10.6	1.4	2.2	4.3	2.6	8.0	3.3

%DI-percentage disease incidence, AUDPC-Area Under Disease Progress Curve

Table 3. 7: Rice blast severity and incidence scores for different rice genotypes during 2017 long rainy season in KALRO -Mwea

Genotypes	Weeks after inoculation						
	1	2	3	4	5	%DI	AUDPC
BS 370	2.7	3.7	5.0	6.0	7.7	89.5	146.2
BW196	0.1	0.1	0.2	0.2	0.2	1.4	5.0
DUORODO	0.6	1.1	1.8	2.3	2.8	5.6	50.7
KOMBOKA	1.9	2.7	3.4	4.5	5.3	69.9	104.0
KUCHUM	1.6	2.2	2.9	3.3	3.6	10.5	80.7
MWUR 4	1.2	2.2	2.5	2.9	3.7	13.9	73.8
NERICA 1	1.2	1.8	2.2	2.8	3.1	10.9	65.2
NERICA 4	1.0	1.8	2.2	2.6	2.9	10.6	61.8
DUO×BS 370	2.7	3.6	4.3	5.1	6.1	59.5	126.5
DUO×KOMB	2.6	3.2	4.0	4.8	5.8	51.1	119.2
DUO×KUCHM	1.3	1.9	2.4	2.8	3.3	13.7	68.7
DUO×MWU 4	1.8	2.4	2.7	3.1	3.5	20.3	79.1
NER 1×BS 370	1.7	3.1	3.4	4.2	5.2	50.5	103.4
NER 1×KOMB	2.3	3.4	4.1	4.6	5.4	51.1	116.6
NER1×KUCHM	2.1	2.9	3.2	3.5	3.7	21.4	90.4
NER 1×MWU 4	1.7	2.3	2.7	3.2	3.5	13.8	78.7
NER 4×BS 370	2.7	4.0	4.5	5.4	6.7	65.9	136.0
NER 4×KOMB	1.5	2.6	2.9	3.3	4.0	30.4	84.3
NER 4×KUCHM	1.7	2.4	2.9	3.1	3.8	24.0	81.3
NER 4×MWU 4	1.7	2.2	2.4	2.8	3.1	7.4	72.2
Grand mean	1.7	2.5	3.0	3.5	4.2	32.8	87.2
LSD (5%)	0.9	0.9	0.9	0.9	0.8	10.1	24.0
CV (%)	10.5	3.2	1.8	3.7	3.3	3.0	3.4

%DI-percentage disease incidence, AUDPC-Area Under Disease Progress Curve

3.4.5 Correlation among rice blast severity, agronomic and yield traits

Genotypes that had early maturity and few productive tillers had lower yield while the genotypes that were tall and had high chlorophyll content had high yield. Genotypes with high number of filled grains, thousand seed weight, longer panicle length and longer grain length had high yield while those with few panicles per plant had lower yield.

Genotypes with high rice blast incidence and severity had lower yield. The weekly disease severity was positively and significantly correlated with Area under disease progress curve. Thus, this showed that the disease was progressing as time increased (Table 3.8).

Table 3. 8: Correlation among rice blast severity, agronomic and yield traits for different rice genotypes during 2016 short rains and 2017 long rains in KALRO-Mwea

Traits	PH	SD	PTL	DH	DA	DM	FG	PP	TSW	PL	GL	GY	week1	week2	week3	week4	week5	DI
SD	0.5*																	
PTL	-0.7*	-0.5*																
DH	-0.9*	-0.2	0.8*															
DA	-0.9*	-0.2	0.8*	1.00														
DM	-0.7*	-0.6*	0.7*	1.0*	1.0*													
FG	0.4	1.0*	-0.2	-0.4	-0.4	-0.4												
PP	-0.8*	0.1	0.8*	0.9	0.9*	0.6*	0.0											
TSW	0.3	1.0*	-0.6*	-0.4	-0.4*	-0.6*	0.8*	-0.5*										
PL	0.3	-0.3	-0.3	-0.3	-0.3	0.1	0.4	-0.6*	-0.3									
GL	0.7*	0.2	-0.1	-0.5*	-0.5*	-0.3	0.2	-0.5*	0.0	0.2								
GY	0.6*	0.9*	-0.5*	-0.4	-0.4*	-0.6*	0.6*	-0.2	0.7*	0.0	0.4							
week1	0.2	-0.9*	-0.1	-0.3	-0.3	0.0	-0.6*	-0.4	-0.9*	0.4	0.1	-0.4						
week2	0.3	-0.7*	-0.1	-0.4	-0.4	-0.1	-0.6*	-0.5*	-0.8*	0.3	0.2	-0.3	1.9*					
week3	0.3	-0.7*	-0.1	-0.4	-0.4	0.0	-0.6*	-0.5*	-0.8*	0.4	0.2	-0.3	1.0*	1.0*				
week4	0.3	-0.7*	-0.1	-0.3	-0.3	0.0	-0.6*	-0.5*	-0.8*	0.4	0.2	-0.3	1.0*	1.0*	1.0*			
week5	0.3	-0.7*	-0.1	-0.3	-0.3	0.0	-0.6*	-0.4	-0.8*	0.4	0.2	-0.3	0.9*	1.0*	1.0*	1.0*		
DI	0.0	-0.6*	0.2	-0.1	-0.1	0.3	-0.7*	-0.1	-1.0*	0.3	0.2	-0.3	0.9*	0.9*	0.9*	1.0*	1.0*	
AUDPC	0.3	-0.7*	-0.1	-0.4	-0.3	0.0	-0.6*	-0.5*	-0.8*	0.4	0.2	-0.3	1.0*	1.0*	1.0*	1.0*	1.0*	0.9*

*Significant at P ≤ 0.05, Plant height, PTL - Productive tillers SD- SPAD, DH-days to heading, DA-days to anthesis, DM – days to maturity, FG-filled grains, PP-panicles per plant, TGW - Thousand grain weight, PL-panicle length, GL-grain length, GY-grain yield, %DI-percentage disease incidence, Week 1 to 5- weeks after inoculation, AUDPC-Area Under Disease Progress Curve.

3.5 Discussion

Rice genotypes were significantly different for all agronomic and yield traits except filled grains, SPAD and 1000 grain weight. The highest plant height was recorded in Duorodo and lowest in BW 196. The cross between Nerica 1and Kuchum produced significantly higher number of productive tillers. Nerica 1, Mwur 4 and BS 370 showed a significantly higher potential of producing panicles/plant. Similarly, Tahir *et al.* (2002), Zahid *et al.* (2005), Kimani (2010) and Malemba *et al.* (2017) observed great variation in plant height, productive tillers and panicles/plant. However, the results contradict with findings of Wolfgang *et al*. (2002) and Yang *et al.* (2007). These findings imply that there was an appreciable amount of genetic variability. Thus, these genotypes could be selected for genetic improvement of both agronomic traits and grain yield. Various authors have reported the importance of genetic variation in breeding of new improved rice varieties (Ismaila et al., 2013; Falconer, 1996; Atlin et al., 2000; Fukai et al., 1999).

Hybrids generated from a cross between Nerica 4 and mwur 4, nerica 1 and kuchum and nerica 1 and komboka showed significantly shorter duration to flowering than BS 370. Significant higher plant height was recorded in a cross between Nerica 4 and Mwur 4 while the cross between Nerica 4 and Komboka had high grain yield. Similarly, Sabesan et al. (2009) and Saravanan et al. (2006) identified good hybrids based on their mean performance and further determined the combining ability of yield and yield components of rice. The hybrids with the desirable traits could be exploited for heterosis breeding or advanced to further breeding cycles to identify useful transgressive segregants (Li et al., 2002; Alam et al., 2004). Plant height variation among the genotypes could be improved through breeding to produce the preferred height by farmers. Previous study by Kimani (2010) and Efisue et al. (2008) in a participatory plant breeding trial reported that farmers preferred tall plants due to ease of harvesting.

The maturity period varied greatly with Nerica 4, Nerica 1 and Mwur 4 matured early while BW 196 and BS 370 were late. Similar findings have been reported by Bing et al. (2005) and Blum (2000) who evaluated rice genotypes for drought tolerance and identified early maturing genotypes. Such genotypes with early maturity could be used to breed early maturing varieties which escape terminal drought (Kirk et al., 1998).

The present study revealed that parent Mwur 4 and Nerica 1 had significant higher grain yield. However, BS 370 which is preferred by consumers and Kenyan farmers had low yield. The findings were in agreement with previous work of Karim et al. (2007) and Singh (2005) that aromatic types have low yields and the trait seems to be strongly linked to low yield. Similarly, previous study by Rad *et al*. (2012) and Muthuram *et al*. (2012) identified genotypes with high grain yield based on their mean performance. These findings indicate that the genotypes with high yield would result in good performing progenies and could be used in a hybridization program to introgress yield traits into adapted low yielding lines with desirable traits (Muthuram *et al*., 2012).

Correlation of traits revealed that genotypes with a high number of filled grains, thousand seed weight, longer panicle length and longer grain length had high yield while those with few panicles per plant had lower yield. Similar findings have been reported by

Ramakrishnan et al. (2006) and Kimani (2010) who worked on association analysis of some yield traits in rice. The correlation of grain yield with other traits like the number of panicles/plant and the number of filled grains per panicle could be used to select for high yielding breeding lines. These suggest that priority should be given to these traits while making selection for yield improvement. Furthermore, simultaneous improvement of all these characters is possible (Ahmad *et al*., 2012).

Correlation of traits is important in selection of desirable plants and can be used to evaluate the value of different traits (Ahmad *et al*., 2012). Genotypes selected based on yield alone could be misleading because yield is controlled by many genes (Ramakrishnan et al., 2006).

The genotypes BW 196, Duorodo, Nerica 4 and the hybrids generated from a cross between Duorodo and Kuchum and Nerica 4 and Mwur 4 had low rice blast severity and incidence. Similar findings have been reported by Sere *et al*. (2011), Saka et al (994), Sasahara and Koizumi, (2004), Kojima et al. (2004) who found lines resistant to rice blast. These findings imply that the genotypes had low disease progression and could be sources of resistance for introgression into the adapted susceptible genotypes. The findings also suggest the likely presence of leaf blast resistance (Saka, 2006).

The study showed that rice genotypes varied significantly under rice blast artificial infection. The genotypes, BW 196, Duorodo, Nerica 4, hybrids generated from a cross between Duorodo and Kuchum, Nerica 1 and Mwur 4 and Nerica 4 and Mwur 4 had low leaf blast severity score and low AUDPC values. This has been reported from previous study that severity of rice blast epidemics is dependent on the infection and sporulation phases of the disease cycle, genotype, environment, diversity of the pathogen that is present and their interaction (Mian *et al*., 2003; Yang *et al.*, 2011). The present study also revealed that the disease was progressing with increase in time. Similar findings have been reported by Saka (2006) and Kojima et al. (2004). This could be explained by the fact that the fungus had to first access the plant by forming a germ tube then develop an appressorium which penetrates the leaf cuticle. When the leaf was repeatedly colonized, the fungus sporulated on the leaf lesions and spread to other rice genotypes (Dean *et al.* 2005).

In general, grain yield is a quantitative trait controlled by many genes; therefore its overall net effect is produced by various yield components interacting with one another (Ramakrishnan et al., 2006). Based on genetic variability and correlation analysis in this study, 1000 grain weight, filled grains per panicle, plant height and panicles per plant seems to be the primary yield contributing characters and could be relied upon for selection of genotypes to improve genetic yield potential of rice. Selection of plants on the basis of these traits would certainly lead to improvement in grain yield. Similar results had been reported by Priya and Joel (2009) and Anbanandan et al. (2009).

CHAPTER FOUR

COMBINING ABILITY FOR AGRONOMIC AND YIELD RELATED TRAITS IN RICE GENOTYPES

4.1 Abstract

Rice is the world's second most important food crop cultivated on approximately 150 million hectares. Lack of new improved varieties to replace the old cultivars is among the constraints affecting rice. The specific objective of this study was to determine the combining ability of both agronomic and yield traits in rice genotypes. Seven genotypes were pollinated in a North Carolina II mating design to generate the F_1 hybrids. The 12 F_2 seeds and 8 parents made a total of 20 entries which were planted at KALRO-Mwea on 27^{th} September, 2016 and 7^{th} July, 2017. Each genotype was planted in a plot size of 3 × 3 m, at inter-row spacing of 20 cm and intra spacing of 15 cm in a randomized complete block design replicated three times. Phenotypic characterization was done by collecting agronomic and yield data namely plant height, productive tillers, SPAD, days to anthesis, days to heading, days to maturity, filled grains,1000 grain weight, panicle length, grain length and grain yield. To determine combining ability, data was analysed using SAS (Version 9.3) program. The study revealed that the mean square GCA (m) were significantly different for all traits except SPAD while for GCA (f) significant difference was recorded in all traits except productive tillers, panicles per plant and thousand grain weight. Further analysis in this study using General Predictability Ratio revealed that agronomic and yield traits were governed by non-additive genes. The parents, Komboka, Mwur 4 and Nerica 4 were good general combiners for grain yield, filled grains and had shorter duration to flowering. The hybrids generated from a cross between Mwur 4 and Nerica 4 and Komboka and Nerica 4 were best specific combiners for grain yield, filled

grains and had minimum days to 50% to flowering. No single parent or specific cross showed combination of all traits hence, to develop a high yielding genotype, a combination of desirable traits may be introgressed into adapted rice genotypes. The three parents with good general combining ability for grain yield could be used in a hybridization program to introgress yield traits into adapted low yielding lines. The two best specific combiners could be exploited for heterosis breeding.

4.2 Introduction

Rice is an important cereal crop and nearly 2.7 billion people in the world depend on it (Tannidi *et al*., 2016). Globally, it is cultivated on approximately 150 million hectares, with production of 500 million metric tons annually (Onyango, 2014). A study by Seck *et al*., (2012) revealed that the total rice consumption in sub-Saharan Africa would rise from 24.0 Mt in 2012 to 36.0 Mt by 2020. Therefore, to overcome the future challenge of food shortage, constraints affecting rice production need to be addressed. The constraints are generally abiotic and biotic factors, poor grain quality and lack of new improved and adapted varieties (Onyango, 2014).

The current varieties grown by farmers in Kenya are home saved seed that are low yielding at around 1t ha^{-1}. They are poorly adapted to the prevailing low soil fertility conditions, susceptible to diseases and have undesirable traits for consumer acceptability (Kimani, 2010). The varieties grown were developed in the early 1980’s and over time, they have degenerated mainly from admixture of different rice seed varieties, increased susceptibility to diseases and pests, slow natural mutations, and some limited cross pollination leading to genetic segregation (Kimani, 2010).

A successful rice breeding programme for developing new improved rice varieties requires an appropriate selection of parents and breeding methods (Torres & Geraldi, 2007). This could be achieved through making crosses using an appropriate mating design which could then be tested against major production constraints such as low yields, disease and pest tolerance, drought tolerance and low temperatures. This is followed by determining the gene action involved in their resistance and their combining ability of agronomic traits and yield components (Gichuru *et al*., 2011). Mating designs like Diallel and North Carolina design II gives GCA and SCA and also heritability which can be broad or narrow sense heritability (Acquaah, 2012).

According to Pradhan and singh (2008), GCA is related to the breeding value of the parents while SCA is associated with non-additive gene action and epistasis. GCA shows the average performance of a line in hybrid combinations and the SCA shows which certain hybrid combinations are either better or poor, than would be expected on the average performance of the parent inbred lines involved (Hallauer *et al*., 2010). Various researchers have reported the predominance of additive and non-additive gene action for various traits (Panwar, 2005; Mahmood *et al*., 2002). Panwar (2005) reported the predominance of additive gene action for seedling height, panicles per plant, grain length, spikelets per panicle and non-additive gene action for the plant height, days to 50% flowering, days to 80% maturity, 1000-grain weight and grain yield per plant. Sharifi

(2012) reported that the higher magnitude of dominance variances showed that non-additive gene action was predominant to additive one. Therefore, in order to establish rice varieties with desirable traits and adapted to local condition, combining ability analysis gives useful information for selection of good parents and promising recombinants for the breeding programme. Such information is also useful in determining the best breeding method for improving specific traits of interest. Therefore, this present study was aimed at determining the combining ability of agronomic and yield traits among selected rice varieties.

4.3 Materials and methods

4.3.1 Experimental site

Kenya Agricultural and Livestock Research Organization (KALRO) - Industrial Crops Research Centre (ICRC) Mwea-Tebere (Formally National Rice and Fiber Research Centre) is located in Mwea Division, Kirinyaga County (Kimani, 2010). The Centre is 24 km South West of Embu town and about 112 km North East of Nairobi. It lies on Latitude 00° 37’S and Longitude 37 ° 20’ E at an elevation of 1159 m above sea level (MASL). The average rainfall is about 850 mm with a range of 500 - 1250 mm divided into long rains (March – June with an average of 450 mm) and short rains (Mid-October to December with an average of 350 mm). The rainfall is characterized by uneven distribution in total amounts, time and space. The temperature ranges from 15.6 ° C to 28.6º C with a mean of about 22° C. The soil is nitosol, which is deep, well drained dusky-red to dark reddish-brown, friable clay with low fertility (Jaetzold and Schmidt, 1983).

4.3.2 Rice germplasm

Seven genotypes were crossed in North Carolina Mating Design II. These varieties were obtained from KALRO-Mwea and had different characteristics (Table 4.1).

Table 4. 1: North Carolina mating design II

Code	Genotype	Origin	Characteristics
1	Basmati 370	Kenya	Aroma, very good cooking quality, susceptible to blast
2	Kuchum	Kenya	Very good cooking quality, susceptible to blast
3	Mwur 4	Kenya	High yield, taller , resistant to blast
4	Komboka	Tanzania	Aroma, high yielding, susceptible to blast
5	Nerica 4	Africa Rice centre	High yield, taller , resistant to blast
6	Duorodo	Kenya	Good grain quality, resistant to blast
7	Nerica 1	Africa Rice centre	High yield, taller , resistant to blast, moderate aroma

Genotypes crossed in North Carolina mating design II

4.3.3 Generation of crosses

Seven rice varieties namely Basmati 370, Kuchum, Komboka, Mwur 4, Nerica 1, Duorodo and Nerica 4 were planted in pots in three sets staggered at 14 and 21 days interval for synchronization of flowering. Each pot was 9cm x 3 cm and had 3 plants per hill. Water was raised to a level of 5 cm after each planting. DAP fertilizers was applied at planting 60 kg P ha^{-1} and top dressed with CAN at the rate of 120 kg N ha^{-1} at 14 days after seeding. Standard agronomic practices were followed to raise a healthy crop in all season (Poehmann, 2006). Rice flowers of the parents were emasculated in preparation for crossing by cutting back the tip of the floret and removing the anthers and clipping back the tip of the lemma and palea. The anthers were removed by tweezers, but the emasculation process was speeded up by using suction emasculator machine. Emasculations were performed in the morning. Flowers were then covered to protect them from natural cross pollination until they open and are ready for pollination. The rice panicles were pollinated in the afternoon following North Carolina II mating design. The pollinated panicles were tagged indicating the parents used in the cross and the date of pollination. At maturity, they were harvested as F_1 seed then planted next season and allowed to self to produce F_2 seeds.

4.3.4 Evaluation of the parents and F_1 population

The 12 F_1's and 8 parents were grown in the greenhouse at KALRO, central Kenya. The 20 entries were planted on 8th April, 2016. A completely randomized design, replicated three times was used. Each pot was 9 cm x 3 cm and had 3 plants per hill. DAP fertilizers was applied at planting 60 kg P ha^{-1} and top dressed with CAN at the rate of 120 kg N ha^{-1} at 14 days after emergence. Normal cultural practices such as weeding were carried out manually (Poehmann, 2006).

4.3.5 Evaluation of F_2 and F_3 segregating population

The F_2 and F_3 seeds generated through North Carolina Design II were evaluated in two seasons at KALRO-Mwea. The 12 F_2 seeds and 8 parents made a total of 20 entries which were planted at KALRO-Mwea on 27th September, 2016 and 7th July, 2017. Each genotype was planted in a plot size of 3 × 3 m, at inter-row spacing of 20 cm and intra spacing of 15 cm in a randomized complete block design replicated three times. A path of one metre was left between replicates to allow for easy movement during data taking. Three seeds per hill were sown and later thinned to one plant per hill. A susceptible local variety namely Basmati 370 was planted as a spreader row around the experimental plots. DAP fertilizers was applied at planting and top dressed with CAN at 14 days after seeding. Normal cultural practices such as weeding were carried out manually. Data was collected on agronomic and yield traits plant height, productive tillers, SPAD, days to anthesis, days to heading, days to maturity, filled grains, 1000 grain weight, panicle length, grain length and grain yield (Poehmann, 2006).

4.3.6 Assessment of agronomic and yield related traits

Days to heading and anthesis were measured by counting days from planting to when 50% of plants in a plot and 50% of tillers per plant had panicle exerted 2/3 way and flowered and shed pollen respectively. Total chlorophyll content of ten randomly plants was recorded at heading stage using SPAD. Days to maturity was measured by counting the number of days from planting to when 80% of grains in the plot were mature. Plant height of ten random plants per replicate was measured in centimeters from the base of the main tiller to the tip of the panicle at maturity. Productive tillers of ten randomly plants per replicate were counted at maturity. A total of seven yield and yield contributing characters were recorded. Grains per panicle of ten randomly plants per replicate were counted at harvest. The 1000 well- developed whole grains of each genotype were dried to 13% moisture content and then weighed on a precision balance. Total number of panicles in a plant was counted for ten randomly selected hills at time of maturity. Total number of filled grains per panicle was counted from ten randomly selected panicles at maturity. The grain length of each ten sampled grain per plot was measured at harvest using a micrometer. Grain yield was harvested and weighed on plot basis.

4.3.8 Data analysis

4.3.8.1 Analysis of Variance

Data were subjected to analysis of variance using Restricted Maximum Likelihood (REML) in GENSTAT 15th edition. Separation of genotype means was done by using the Fishers protected Least Significant Difference LSD) at 5% level. The collected data were analyzed by SAS (Version 9.3) program.

1.3.8.2 General combining ability (GCA) and specific combining ability (SCA) effects

The estimates of GCA and SCA of parents and progenies were calculated as:

$$\text{GCA effect} = \frac{1}{n[n-2]} \quad n(nxi - 2x\ldots)$$

$$\text{SCA effect} = 1 = \frac{1}{n-2} \quad (x_i + x_j) + \frac{2}{(n-1)\,n-2} \quad x$$

Where, *xi*, x_j = means of the i^{th} and j^{th} parents, respectively; *x* = grand mean; *n* = number of parental lines

The relative importance of GCA and SCA were estimated using the general predicted ratio for the traits observed (Baker, 1978).

$$\frac{\sigma^2\,\text{GCA (female)} + \sigma^2\text{GCA(male)}}{\sigma^2\,\text{GCA (female)} + \sigma^2\text{GCA(male)} + \sigma^2\text{SCA}}$$

Where,

σ^2GCA (female) indicates variance components for general combining ability of female,

σ^2 GCA (male) indicates variance components for general combining ability for male and

σ^2 SCA indicates the variance components for specific combining ability.

1.3.8.3 Estimation for the narrow sense heritability

Estimation for the narrow sense heritability was done by use of the Plant Breeding Tools Version: 1. (Nyquist, 1991).

$$\text{Heritability (H)} = \frac{V_g}{V_p}$$

Where, Vg =genotypic variance, Vp= phenotypic variance

4.4 Results

4.4.1 Agronomic and yield traits

The mean square GCA (m) were significantly different for all traits except SPAD while for GCA (f) significant difference was recorded in all traits except productive tillers, panicles per plant and thousand grain weight. Specific Combining Ability showed significant differences for all traits measured. The GPR ranged from 0.5 to 0.7 for agronomic traits and 0.5 to 0.8 for yield traits (Table 4.2). Broad sense heritability (H^2) was greater than Narrow sense heritability (h^2) for both agronomic and yield traits. Non-additive gene action was more important than additive gene action (Table 4.3).

Table 4. 2: Analysis of variance for the combining ability of agronomic and yield traits for different rice genotypes during short and long rainy season in KALRO-Mwea

		Agronomic traits						Yield traits					
Source of variation	Df	PH	PTL	SD	DM	DH	DA	PP	TGW	PL	GL	GY	FG
Replication	4	189.9	12.0	87.6	28.9	75.7	91.4	13.6	30.0	4.5	0.3	2.6	115.4
Season	1	2274.8*	268.0*	21.1	105.1*	44.3	51.2*	4.1	5.0*	2.0*	0.6*	8.5*	1168.1*
Genotype	11	626.1*	16.1*	58.7*	858.7*	459.5*	455.9*	8.9*	6.6*	28.1*	5.1*	27.2*	4858.2*
Season x genotype	11	128.6*	4.1	18.6	0.5	84.3*	92.9*	8.2*	8.4*	6.2*	0.4	1.2	200.6
GCA (m)	3	397.3*	25.8*	27.4	314.5*	111.9*	129.2*	13.2*	7.1*	5.4*	0.6*	28.3*	5831.2*
GCA (f)	2	535.1*	4.0	45.9*	1488.2*	735.5*	782.0*	2.7	2.9	84.8*	6.0*	32.9*	2882.0*
SCA (m x f)	6	770.8*	15.3*	78.5*	920.9*	541.3*	510.5*	8.9*	7.5*	20.5*	7.1*	24.7*	5030.4*
Residuals	44	144.3	8.7	56.6	68.8	91.8	96.6	8.6	5.2	3.4	0.7	3.5	468.7

Proportional contribution to the total variance

Source of variation	Agronomic traits						Yield traits					
	PH	PTL	SD	DM	DH	DA	PP	TGW	PL	GL	GY	FG
Male	397.3	25.8	27.4	314.5	111.9	129.2	13.2	7.1	5.4	0.6	28.3	5831.2
Female	535.1	4.0	45.9	1488.2	735.5	782.0	2.7	2.9	84.8	6.0	32.9	2882.0
Males x Females	770.8	15.3	78.5	920.9	541.3	510.5	8.9	7.5	20.5	7.1	24.7	5030.4
GPR	0.6	0.7	0.5	0.7	0.6	0.6	0.6	0.6	0.8	0.5	0.7	0.6

* Significant at $P \leq 0.05$, PH - Plant height, PTL - Productive tillers SD- SPAD, DM –days to maturity, DH-days to heading, DA-days to anthesis, PP-panicles per plant, TGW - Thousand grain weight, PL-panicle length, GL-grain length, GY – Grain yield, FG-filled grains,

Table 4. 3: Heritability and additive (A) and dominance (D) variance for agronomic and yield traits for different rice genotypes during short and long rainy season in KALRO-Mwea

	Agronomic traits						Yield traits					
	PH	PTL	SD	DM	DH	DA	PP	TGW	PL	GL	GY	FG
V_A	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	1.1	0.0
V_D	417.7	4.4	14.6	568.1	299.7	276.0	0.2	1.6	11.4	4.3	14.2	3041.1
Narrow sense (h^2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0
Broad sense (H^2)	0.7	0.3	0.2	0.9	0.7	0.7	0.0	0.1	0.7	0.8	0.7	0.8

* Significant at $P \leq 0.05$, PH - Plant height, PTL - Productive tillers SD- SPAD, DM –days to maturity, DH-days to heading, DA-days to anthesis, PP-panicles per plant, TGW - Thousand grain weight, PL-panicle length, GL-grain length, GY – Grain yield, FG-filled grains

4.4.2 General combining ability effects of for agronomic and yield related traits in rice genotypes

The parents, Nerica 1, Komboka, Nerica 4 and Mwur 4 were good combiners for days to flowering with negative GCA effects. Kuchum, Duorodo and Mwur 4 were good general combiners for plant height with negative GCA while for SPAD, Komboka and Nerica 1 were good combiners with positive GCA. All parents were good general combiners for productive tillers except Komboka, mwur 4 and Duorodo. On the other hand, Komboka, Nerica 4 and Mwur 4 were good general combiners for grain yield but not for panicles/plant. For 1000 grain weight, Kuchum and Nerica 4 were found to be good general combiners with positive GCA effects while Komboka, Mwur 4, Nerica 4 and Duorodo were good general combiners for filled grains. No single parent contained all desirable traits. Overally, Mwur 4, Komboka and Nerica 4 were best parents for grain yield, filled grains and had shorter duration to flowering (Table 4.4).

Table 4. 4: General combining ability of rice parents for agronomic and yield traits during short and long rainy season in KALRO-Mwea

	Agronomic traits						Yield traits					
Parents	PH	TL	SD	DM	DH	DA	PP	TGW	PL	GL	GY	FG
BS 370 (P1)	0.9	0.9	-0.6	5.5*	3.0**	3.5*	0.6	-0.7	-0.6	0.2	-1.0	-24.6
Kuchum (P2)	-5.9*	1.2	-0.4	-3.8	0.5	0.3	0.7	0.8	0.1	0.0	-1.0	-1.6
Mwur 4 (P3)	-0.6	-0.9	-0.8	0.9	-0.6	-0.8	-1.2*	-0.1	-0.2	-0.2*	0.3	10.0
Komboka (P4)	5.6	-1.2	1.8	-2.7	-3.0	-3.0	-0.1	-0.1	0.7*	0.0	1.6*	16.2*
Nerica 4 (P5)	2.6**	0.1	-0.1	-1.6*	-1.5	-1.6	-0.1	0.3	0.5	0.3	1.2*	9.0
Duorodo (P6)	-5.5*	-0.5	-1.3	8.6*	6.1*	6.3*	-0.2	-0.4	1.6	-0.6*	-1.1	3.2
Nerica 1 (P7)	2.9	0.4	1.4	-7.0	-4.7	-4.7	0.4*	0.0	-2.1*	0.3	-0.1	-12.2*

*Significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$ PH - Plant height, PTL - Productive tillers SD- spad, DH-days to heading, DA-days to anthesis, DM –days to maturity, FG-filled grains, PP-panicles per plant, TGW - Thousand grain weight, PL-panicle length, GL-grain length, GY-grain yield (t/ha)

4.4.3 Specific combining ability effects for agronomic and yield related traits in rice hybrids

The hybrids generated from crosses between P5 and P3, P7 and P2, P6 and P1 and P5 and P4 were best specific combiners for minimum days to 50% flowering with negative SCA. The hybrids generated from crosses between P5 and P2, P7 and P3 were the best specific combiners for plant height with negative GCA. On the other hand, hybrids generated from crosses between P6 and P3, P5 and P1, P7 and P1, P5 and P4 and P7 and P2 were best specific combiners for productive tillers with positive SCA.

The best specific combiners for grain yield were hybrids generated from crosses between P6 and P2, P5 and P4 and P5 and P3 with positive SCA effects. The three hybrids had also positive GCA for filled grains. A hybrid generated from a cross between P5 and P3 was the best specific combiner for panicles/plant while a hybrid generated from a cross between P5 and P4 was the best for thousand grain weight. For panicle length hybrids generated from crosses between P7 and P3and P5 and P3 were the best specific combiners. Overall, hybrids generated from crosses between P5 and P3 and P5 and P4 were the best crosses for grain yield, filled grains and had minimum days to 50% days to flowering (Table 4.5).

Table 4. 5: Specific combining ability of rice hybrids for agronomic and yield traits during short and long rainy season in KALRO-Mwea

		Agronomic traits						Yield traits					
Code	Crosses	PH	TL	SD	DM	DH	DA	PP	TGW	PL	GL	FG	GY
P5x P1	Nerica 4 x Bs370	3.7	1.3	-4.5	6.3*	8.2	7.5	-0.9	-1.0	0.9	0.0	-14.4*	-1.8
P6x P1	Duorodo x s B370	2.1	-1.5	0.8	-6.7	-8.2	-7.2	0.8	-0.2	-1.0	-0.6*	3.4	0.5
P7x P1	Nerica 1x Bs 370	-5.8	0.3	3.6	0.4	0.0	-0.4	0.1	1.2	0.0	0.6*	10.9	1.3
P5x P2	Nerica 4 x Kuchum	-14.1**	-0.5	-1.6	12.2	7.4	7.6	0.2	0.8	0.1	-0.8	-11.4	-1.1
P6x P2	Duorodox Kuchum	4.8	-0.8	2.7	-12.8*	1.2	0.9	0.9	-0.1	-0.7	0.0	20.4	2.2
P7x P2	Nerica 1x Kuchum	9.2	1.2	-1.1	0.6	-8.6	-8.5	-1.1	-0.8	0.6	0.8**	-9.0	-1.1
P5x P3	Nerica 4x Mwur 4	10.8*	-1.2	2.2	-14.3**	-13.3**	-13.2*	1.3	-1.0	1.2	0.6	7.2	1.3*
P6x P3	Duorodo x Mwur 4	1.3	2.4	-0.4	16.9***	5.3	5.0	-1.7	0.5	1.4	1.6	19.8*	-0.3
P7x P3	Nerica 1x Mwur 4	-12.2	-1.3	-1.8	-2.6	8.0	8.2	0.5	0.5	-2.5*	-1.7***	-27.0**	-1.0
P5x P4	Nerica 4x Komboka	-0.5	0.4	3.9	-4.2	-2.3	-1.9	-0.6	1.2	-2.2	0.3	18.6**	1.7***
P6x P4	Duorodo x Komboka	-8.3	-0.1	-3.2	2.6	1.7	1.3	0.0	-0.2	0.2	-0.5*	-43.7	-2.4
P7x P4	Nerica 1x Komboka	8.8**	-0.3	-0.7	1.6	0.6	0.6	0.6	-0.9	1.9	0.3	25.1*	0.8*

* Significant at P ≤ 0.05, ** Significant at P ≤ 0.01. *** Significant at P ≤ 0.001, PH - Plant height, PTL - Productive tillers SD- SPAD, DM –days to maturity ,DH-days to heading, DA-days to anthesis, PP-panicles per plant, TGW - Thousand grain weight, PL-panicle length, GL-grain length, FG-filled grains, GY-grain yield (t/ha)

4.5 Discussion

The mean square GCA (m) were significantly different for all traits except SPAD while for GCA (f) significant difference was recorded in all traits except productive tillers, panicles per plant and thousand grain weight. SCA showed significant differences for all traits measured. Similar results were reported by Ismaila et al. (2012), Kimani (2010) and Malemba et al. (2017) who worked on combining ability studies in rice. The findings indicate a wide range of genetic variation among the genotypes thus these genotypes could be selected for genetic improvement of grain yield and other agronomic traits. Previous researchers have reported the importance of genetic variation in breeding of new improved varieties (Falconer, 1996; Ismaila et al., 2012).

The significance of GCA and SCA variance for most of the traits evaluated suggested the importance of both non-additive and additive gene actions in expression of these traits. Further analysis in this study using GPR (Baker, 1978) showed that agronomic and yield traits such as days to anthesis, number of tillers, days to heading, panicle length, thousand grain weight and grain yield were governed by non-additive genes. Similar results were reported by Sharifi (2012), Kumar *et al*. (2008), Mehmood *et al*. (2002) and Yogameenaki *et al*. (2015). However, these findings differed from Panwar (2005) and Bansal *et al*. (2000) who reported the predominance of additive gene action for these traits. Hybridization followed by selection in later generations may be recommended for improvement of these traits.

The present study revealed parents with good combining ability for grain yield and duration to flowering namely Komboka, Mwur 4 and Nerica 4. Previous researchers have identified good parents based on their mean performance for agronomic and yield traits and also GCA effects (Muthuram *et al*., 2010; Rad *et al*., 2012). Generally, parents with positive GCA and high mean performance are preferred for positive traits of grain yields while parents with low estimates and negative GCA are suitable for negative traits of grain yield such as plant height and days to 50% flowering. High GCA effects show broad adaptation and ability of parents to generate hybrids with high acclimatization potential over a range of environments (Rad *et al*., 2012).

The hybrid combinations with high mean performance, best specific combiner for yield and involving at least one of the parents with high GCA were identified in this study. These were hybrids generated from crosses between mwur 4 and Nerica 4 and Komboka and Nerica 4. Similar findings have been reported by Alam *et al*. (2004) who worked on genetic basis of heterosis and inbreeding depression in rice. This implies that these hybrids would likely enhance the concentration of favorable alleles and thus yield desirable progenies (Kenga *et al*., 2004; Li *et al*., 2002; Zhang *et al*., 1994).

The study revealed best specific combiners for most traits evaluated. The hybrids generated from crosses between Mwur 4 and Nerica 4 and Komboka and Nerica 4 were best specific combiners for grain yield, filled grains and 50% days to flowering. Previous study by Li *et al*. (2002) who worked on analysis of heterosis of main agronomic traits in indica-japonica lines of rice identified best specific combiners. The findings indicate that the hybrids would yield desirable progenies. SCA has a relationship with heterosis therefore these the two specific combiners could be exploited for heterosis breeding.

The present study revealed that none of the genotypes were best combiners for all the traits evaluated. Various authors have reported similar findings (Panwar *et al*., 2005; Singh *et al*., 2007). The findings indicate that the genotypes were genetically diverse. This shows that they could be selected for different traits for further improvement.

The heritability results indicated that variance for broad sense heritability was greater than the variance for narrow sense heritability for all traits evaluated. This suggests the importance of non- additive genetic variance. Previous study by Ali *et al*., 2000 reported significant broad sense heritability for some yield and yield components. These findings differed from Panwar (2005) and Bansal *et al*. (2000) who reported the predominance of additive gene action for these traits. The presence of non-additive gene action offers scope for exploiting hybrid vigour through heterosis breeding in rice and hence these genotypes can be exploited for production of commercial hybrids (Andrzej et al., 2011; Munganyika *et al*., 2015; Mutengwa *et al*., 2012).

CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

The general combining ability results revealed the presence of the parents with good general combining ability for various agronomic and yield traits namely Mwur 4 and Nerica 4. These parents contributed to the formation of hybrids with good specific combining ability for agronomic and yield traits. According to Gakunga *et al*. (2012), identification of gene actions responsible for the control of traits of interest such as resistance to disease, general combing ability and specific combining ability are useful factors to be considered in improvement of crops. Thus, these parents could be selected for yield improvement in rice breeding program.

For specific combining ability, hybrids generated from crosses between Mwur 4 and Nerica 4 and Komboka and Nerica 4 were best specific combiners for grain yield, filled grains and 50% days to flowering. All these crosses had either shared one of the good parent combiner with high yield traits implying that these hybrids will eventually yield desirable progenies (Li et al., 2002; Alam et al., 2004). Thus, these hybrids could be advanced to the next generation and tested in different environments for yield stability and then be released as new varieties to be used by the farmers.

The heritability results indicated that variance for broad sense heritability was greater than the variance for narrow sense. This emphasizes that non-additive genetic variance was more important in controlling agronomic and yield traits in rice. The non-additive gene action plays a critical role in choice of elite hybrid combinations in breeding programs. Thus, suggesting the importance of choosing suitable segregating generations which could exhibit the best expression of genes of different traits and also for improving such traits (Reddy and Jabeen, 2016).

Correlation of traits revealed that genotypes with a high number of filled grains, thousand seed weight, longer panicle length and longer grain length had high yield while those with few panicles per plant had lower yield. This could be used to select for high yielding breeding lines. Genotypes selected based on yield alone is misleading since yield is controlled by many genes (Ramakrishnan et al., 2006). Furthermore, simultaneous improvement of all these traits is possible.

The present study revealed that the disease was progressing with time. This could be explained by the fact that the fungus had to first access the plant by forming a germ tube then develops appressorium which penetrates the leaf cuticle. When the leaf was repeatedly colonized, the fungus sporulated on the leaf lesions and spread to other rice genotypes (Dean *et al.* 2005).

The study showed that rice genotypes varied significantly under rice blast artificial infection. The genotypes, BW 196, Duorodo, Nerica 4, hybrids generated from a cross between Duorodo and Kuchum, Nerica 1 and Mwur 4 and between Nerica 4 and Mwur 4 had low leaf blast severity score and low AUDPC values. This has been reported from previous study that severity of rice blast epidemics is dependent on the infection and sporulation phases of the disease cycle, genotype, environment, diversity of the pathogen that is present and their interaction (Mian *et al*., 2003; Yang *et al.*, 2011). These genotypes means had low disease progression and could serve as sources of resistance for improving adapted susceptible rice genotypes. The findings also suggest the likely presence of leaf blast resistance. Similar findings have been reported by Sere *et al*., 2011, where varieties like IR64, IR6203 and OM1570 were found to possess durable resistance.

5.2 Conclusion

Three parents namely Mwur 4, Komboka and Nerica 4 were good general combiners for grain yield and could be used in a hybridization program to introgress yield traits into adapted low yielding lines. The hybrids generated from a cross between Mwur 4 and Nerica 4 and between Komboka and Nerica 4 showed good SCA for grain yield, filled grains and 50% days to flowering. These hybrids could be advanced to the next generation and tested in different environment for yield stability and then be released as new varieties to be used by the farmers. No single parents or specific cross showed combination of all traits hence, to develop a high yielding genotype, a combination of desirable traits may be introgressed into adapted rice genotypes. Non additive gene action was predominant for all traits, this offers scope for exploiting hybrid vigour through heterosis breeding in rice and hence these genotypes could be exploited for production of commercial hybrids.

The study showed that some of rice varieties are potential sources of rice blast resistance sources; these were BW 196, Duorodo, Nerica 4, hybrids generated from a cross between

Duorodo and Kuchum, Nerica 1 and Mwur 4 and between Nerica 4 and Mwur 4. These could serve as potential donors to improve adapted susceptible rice genotypes.

5.3 Recommendations

1. The two promising hybrids are recommended for further evaluation in preliminary and advanced yield trials while the three parents with good combining ability are recommended be used in a hybridization program to introgress yield traits into adapted low yielding lines.
2. The genotypes should be further screened under different environments for several seasons to conclusively determine resistance to prevalent races of the blast pathogen. There is also need to characterize blast fungus genetic diversity and conduct genetic studies.

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APPENDIX

Appendix 1: Weather data collected during a field trial in KALRO-Mwea

Date	Humidity (%)	Temperature (ºC)	Rainfall (mm)
1/8/2016	59.2	18.9	0
2/8/2016	69	16.9	0
3/8/2016	62.6	17.3	0
4/8/2016	58.2	20.3	0
5/8/2016	57.3	20.2	0
6/8/2016	64.9	19.8	0
7/8/2016	68.6	18.7	0
8/8/2016	57.6	20.2	0
9/8/2016	82.2	18.6	0.2
10/8/2016	91.1	16.9	0.5
11/8/2016	61.2	18.9	0
12/8/2016	70.6	19	0
13-08-2016	76.4	18.6	1.5
14-08-2016	73.7	18.9	0
15-08-2016	69.5	19.7	0
16-08-2016	69.4	19.6	0
17-08-2016	80.5	14.7	0
18-08-2016	56.4	20.4	0
19-08-2016	56.6	20.2	0
20-08-2016	61.9	19.2	0
21-08-2016	63.9	19.7	0
22-08-2016	67.4	19.5	0
23-08-2016	60.6	19.6	0
24-08-2016	74.8	15.4	0
25-08-2016	52.2	18.1	0
26-08-2016	69	15.6	0
27-08-2016	82.5	14.1	0.2
28-08-2016	57.8	16.3	0
29-08-2016	51.1	19.7	0.5
30-08-2016	69.2	18.4	0
31-08-2016	57.2	19.8	0
1/9/2016	59.9	19.6	0
2/9/2016	68.5	18.3	0
3/9/2016	62.7	18.6	0
4/9/2016	63.1	18.9	0.2
5/9/2016	70.6	18.4	0.2
6/9/2016	66.7	19.3	0
7/9/2016	75.4	16.1	0
8/9/2016	75.9	16.9	0

Appendix 1: Weather data collected during a field trial in KALRO- Mwea

Date	Humidity (%)	Temperature (ºC)	Rainfall (mm)
9/9/2016	73.5	15.1	0
10/9/2016	62.4	18.7	0
11/9/2016	68.2	20.2	0
12/9/2016	71.7	15.5	0
13-09-2016	69.5	17.1	0
14-09-2016	66.4	18.9	0
15-09-2016	71.9	19	0
16-09-2016	49.3	20.4	0
17-09-2016	61.2	18.7	0
18-09-2016	61.9	18.2	0
19-09-2016	53	20.5	0
20-09-2016	62.7	19.3	0
21-09-2016	62.4	18.4	0
22-09-2016	59.9	19.4	0
23-09-2016	60.3	19.3	0
24-09-2016	61.2	20.6	0
25-09-2016	54.1	22.1	0
26-09-2016	56.6	21.6	0
27-09-2016	48.9	21.6	0
28-09-2016	53	21.6	0.7
29-09-2016	91.6	18.3	2
30-09-2016	66.6	21.2	0
1/10/2016	58.6	20.8	0
2/10/2016	60	21	0
3/10/2016	68.8	20.1	0
4/10/2016	53.8	22.8	1.2
5/10/2016	78.5	19.8	0.2
6/10/2016	61.5	21.4	0.2
7/10/2016	59	21.6	0
8/10/2016	46.5	23.2	0
9/10/2016	62.6	22.3	0
10/10/2016	55.6	22.4	0
11/10/2016	55.6	22.1	0
12/10/2016	47.7	22.8	0
13-10-2016	45.8	21.1	0
14-10-2016	45.1	21	0
15-10-2016	54.4	19.7	0
16-10-2016	49.4	21.2	0
17-10-2016	49.3	21.9	0
18-10-2016	58.8	19.8	0
19-10-2016	49	21.1	0

Appendix 1: Weather data collected during a field trial in KALRO-Mwea

Date	Humidity (%)	Temperature (ºC)	Rainfall (mm)
20-10-2016	54.8	22.2	0
21-10-2016	51.1	21.6	0
22-10-2016	52.2	22.3	0
23-10-2016	58	19.7	0
24-10-2016	52.7	19.9	0
25-10-2016	55.7	21.4	0
26-10-2016	59.7	21	0
27-10-2016	58.1	19.5	0
28-10-2016	69.3	21.1	1.2
29-10-2016	90.1	17.1	0.2
30-10-2016	68.1	19.2	0
31-10-2016	68.2	18.3	0
1/11/2016	72.9	21.4	0
2/11/2016	70.9	20.2	0
3/11/2016	75.5	20.3	0.2
4/11/2016	91.9	19.2	0
5/11/2016	88.5	19.6	0
6/11/2016	74.1	20.3	0
7/11/2016	75.5	19.1	0
8/11/2016	66.5	20.9	0
9/11/2016	63.4	20.6	0
10/11/2016	81.8	19.4	0
11/11/2016	91.2	17.3	0
12/11/2016	79.2	18.2	0
13-11-2016	62.5	20.9	0
14-11-2016	81.5	16.9	0
15-11-2016	85.1	17	0.2
16-11-2016	84.2	19.4	0
17-11-2016	93.9	18.8	0
18-11-2016	93.4	18	0.2
19-11-2016	93.9	18.7	0
20-11-2016	93.9	16.8	0
21-11-2016	95.4	18	0
22-11-2016	97.9	19.2	0
23-11-2016	74.5	19.5	0
24-11-2016	87.4	20.4	0.2
25-11-2016	95.6	18.7	0
26-11-2016	92.3	20.2	0
27-11-2016	93.3	19.3	0
28-11-2016	89.8	17.5	0
29-11-2016	93.9	19.6	0