POTENTIAL OF SELECTED SORGHUM LINES FOR PRODUCTION OF HYBRIDS FOR DRY AGRO-ECOLOGIES OF EAST AFRICA

BY

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DECLARATION

Declaration by the Candidate

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DEDICATION

To my wife Ndekusura Ringo, my mother Suzana Malyamoya and entire family for the love, passion, consistent and unreserved support all through my study period.

ABSTRACT

Sorghum (*Sorghum bicolor* L. Moench) is staple crop to farmers living in dry lands and sub-humid areas of East Africa, but yield is low (<1tha^{-1}) due to lack of hybrids. Hybrid sorghum can significantly increase productivity. Hybrid development requires diverse and adapted parental lines. A study was conducted between 2010 and 2012 using 121 ICRISAT sorghum lines at selected dry lowland (Kiboko and Miwleni) and sub-humid (Ukiriguru) agro-ecologies to determine performance and genetic diversity, develop test hybrids and assess the heritability of yield and its components, and the combining abilities. There were significant ($p \leq 0.05$) phenotypic variations among the sorghum lines and hybrids for yield and its related trait. Highest yielder was ICSR93034, (4.0 t/ha) while the check yielded 2.3t/ha. There was significant genotype and genotype-by-environment interaction suggesting importance of evaluating breeding materials under different agroecologies for effective exploitation of plant vigour. IESV91104DL and IESV91131DL are suitable for dry lowlands whereas IESV23019 and KARI MTAMA1 are for sub-humid environments. These lines yielded high, took short period to flower indicative of early maturity; and were short stature suitable for dry lands and sub-humid environments. Some A's *viz* A2DN55, ICSV189, ICSA452, ICSA479, ICSA73, ICSA77 and ICSA469 had low and inconsistent restoration, 0 to 20% and should be avoided in hybrid development programs. Plant height was highly heritable (0.96). Awns at maturity expressed highest genotypic coefficient of variation (GCV%) and phenotypic coefficient of variation (PCV%) across locations. Lines IEBS2, ICSB15, BTX623, IESV91104DL, IESV91131DL and KARI-MTAMA1 were top general combiners for yield and days to 50% flowering (DAF). Hybrids ICSA44×IESV91104DL, ICSA15×IESV91104DL, TX623×IESV91104DL and ICSA12×KARI-MTAMA1 yielded high (6.9t/ha), matured early, 60 to 63 DAF, and had good stature (1.1 m to 2.3m) tall. Heterobeltiosis for DAF varied from -5.23 to -14% indicative of early maturity and can escape terminal drought in rain-fed agriculture which is the characteristic of East African cultivation system. Heterotic response for yield and its components resulted from some cross combinations facilitate to develop high yield sorghum hybrids and varieties suitable for the dry lowland and sub-humid environments than the currently grown genotypes in the region. It is confirmed that significant diversity and hybridity potential exist in sorghum collections held at ICRISAT. Identified genotypes in this study could be advanced to National Performance Trials (NPT) for commercial release in Tanzania and Kenya. Future evaluation for drought tolerance should not involve Kiboko and Miwaleni together, one of the two can give enough information.

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

CMS	Cytoplasmic male sterility
FAO	Food and Agriculture Organization
GCA	General Combining Ability
GCV	Genotypic Coefficient of Variation
GMS	Genetic male sterility
IBPGR	International Board for Plant Genetic Resources
ICRISAT	International Centre for Research in Semi Arid Tropics
IPCC	Intergovernmental Panel on Climate Change
MAFSC	Ministry of Agriculture Food Security and Cooperatives
NARS	National Agricultural Research Station
NSMIP	National Sorghum and Millet Improvement Program
PCV	Phenotypic Coefficient of Variation
SCA	Specific Combining Ability
SMIP	Sorghum and Millet Improvement Program
USAID	United States of America Agency for International Development
^{o}C	Degree Celsius
N	Nitrogen
P	Phosphorus

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CHAPTER ONE

INTRODUCTION

1.1 General Overview

Sorghum (*Sorghum bicolor* L. Moench) is one of the most important drought tolerant cereals and is grown in arid and semi-arid parts of Africa (Abdulai et al., 2012). Sorghum contributes to food security; it has high calorie content, and also provides metallic nutrients, particularly iron and zinc, which makes it competitive with maize (Koenders, 2010). In spite of its importance, sorghum yield in East Africa is low (<1t ha^{-1}) mainly because of the traditional farming practices characterized by use of low yielding cultivars and landraces that are susceptible to water stresses, among other environmental factors.

Climate change models indicate that many parts of Africa shall experience reduced and erratic rainfall as temperatures increase (Rowhani et al., 2011). Therefore, the importance of drought tolerant cereals, especially sorghum is likely to increase as the staples in the continent. Furthermore, the emerging market for sorghum in the brewing industry should create high demand especially for the white varieties. Deployment of adapted sorghum cultivars can significantly increase yields in sorghum growing areas including the dry and sub-humid agroecologies of East Africa (House et al., 1997).

Development of high yielding and adapted cultivars is possible through targeted breeding, multilocational testing and effective selection procedures. Furthermore, cytoplasmic male sterility (*cms*) in sorghum can facilitate hybrid seed production. Hybrid sorghum can provide a 20 to 60% grain yield advantage over open pollinated varieties in similar environments (Makanda et al., 2012). Hybrid sorghum has been recorded to yield up to 6.2 t ha^{-1} (Patil, 2007). Apart from all benefits and potential for yield improvement, there has been no sorghum hybrid developed purposely for the dry or sub-humid agroecologies of East Africa. This is probably due to lack of well characterized heterotic parental lines.

Establishment of sustainable sorghum hybrid programs requires availability of locally adapted male sterile (A) and male fertile/restorer (R) lines. The ideal R-lines must have high restoration capacity based on seed set of selfed F_1s. According to Singh et al., (1997), the hybrid with full seed set on all bagged panicles shows that the parents are compatible if the hybrid is fully fertile. In this case it means the corresponding male parents are good restorer lines for hybrid production especially if the F_1 is fully restored over several environments since the intention is to grow the resultant hybrid in wide ranging environments.

Genetic improvement depends on the availability of genetic diversity in the selection material, and its efficient exploitation. In other parts of the world, sorghum breeders have been crossing an elite variety with another elite variety to develop rapidly and release new varieties for commercial cultivation (Chandrasekara et al., 2011). However, such elite x elite crosses have an advantage of accumulating genes involved in grain yield expression, provided elite lines are from diverse sources. Crossing two elite lines with related parentage does not give significant advantage in terms of grain yield (Audilakshmi et al., 2003). Hence, the narrow genetic base in the germplasm of a breeding program affects the potential genetic gain through selection.

Good knowledge of the genetic diversity, heritability, combining ability and heterosis of genotypes are essential in any effective breeding program. Generally high variability of genotypes could lead to higher improvement of a crop when the genotypes are crossed (Jain and Patel, 2012). The genotypic coefficient of variation along with heritability estimates provide reliable estimates of the amount of genetic advance to be expected through phenotypic selection. Combining ability of the parental lines is an important factor in hybrid breeding programs (Vinaykumar et al., 2011) because it is very closely associated with *per se* performance of the line in crops including sorghum (Tadesse et al., 2008). Analysis of combining ability and estimation of degree of heterosis gives an indication of nature of gene action, desirable parents and important yield traits particularly in crops which are aimed for production of F_1 hybrid seed using cytoplasmic male sterility such as sorghum (Mahdy et al., 2011)

Performance of hybrids is estimated from the percentage increase or decrease of their performance over the mid parent (average heterosis) and better parent (heterobeltiosis) (Hochholdinger and Hoecker, 2007). Positive average heterosis and heterobeltiosis in a desired direction is preferred in selection for yield and its components (Lamkey and Edwards, 1999). Contrary, positive heterosis and heterobeltiosis is not preferred for plant height and days to flowering as it implies increased height, which tends to be closely associated with lodging, and increased days to flowering hence delayed maturity. The successful hybrid sorghum program depends on the magnitude of heterosis which enables identification of potential cross combinations. The high yield potential restorer(s) from cross combinations can also be advanced and released as a commercial variety(s). Sorghum inbred lines and landraces collected from ICRISAT were used to develop hybrids, study levels of fertility restoration, genetic diversity, combining ability and heterosis in selected sub-humid and dry agroecologies of East Africa.

1.2 Statement of the Problem and justification

The average sorghum yields in small scale farmers fields in the region is very low partly because farmers do not grow high yielding pure line or hybrid varieties. Hybrid sorghum seed is unavailable in the region. ICRISAT has several male sterile and restorer sorghum that could be used in hybrid sorghum production but there is limited knowledge on their genetic diversity and heterotic potential.

Demand for sorghum grain in East Africa is high and fast increasing due to its multiple uses. To meet out such demand, the increase in the production should come from same or even less area in the present situation of shrinking agricultural land due to climate change. Hybrid sorghum are a better option due to their high grain yield potential. Availability of such materials could significantly increase grain yield in semi-arid areas of East Africa.

In addition, given that hybrid sorghum production is founded on male sterile and restorer lines, the present study attempted to determine performance and genetic diversity of sorghum lines held by ICRISAT; develop and test hybrids for restoration fertility. The study also aimed to determine heritability for yield and yield components; hybrid vigour and the combining abilities at two different agroecologies for adaptation.

The research gaps that this study was set up to address with regard to sorghum improvement in East Africa included:

i. Lack of hybrid sorghum cultivars adapted to the semi-arid and sub-humid agro-ecologies of East Africa.
ii. No studies have been done to determine fertility restoration status of introduced hybrid parental lines at ICRISAT-Nairobi.
iii. Limited information on genetic diversity, heritability of yield and its components of available sorghum germplasm at ICRISAT-Nairobi that could serve as parents in a hybrid breeding program.
iv. Limited knowledge on levels of heterosis and combining ability of sorghum parental lines in East Africa.

1.3 Objectives

Overall objective of this research was to evaluate the potential of available sorghum inbred lines for use as varieties, and/or developing hybrids for the dry and sub-humid agroecologies of Tanzania and Kenya.

The specific objectives were to:-

i. Establish genetic diversity of the selected sorghum genotypes in dry and sub-humid environments using morphological characters.
ii. Determine performance of experimental hybrid sorghum in selected dry low lands and sub-humid environments of East Africa
iii. Determine heritability of yield and its components in the various hybrids in selected dry and sub-humid environments
iv. Identify general and specific combining abilities of hybrid parents across dry lands and sub-humid agroecologies of Eastern Africa for yield and its components

1.4 Research Hypothesis

The diversity of germplasm available in the Eastern African region is high enough to support a sorghum hybrid breeding program for the sub-humid and arid agroecologies of Eastern Africa.

CHAPTER TWO

LITERATURE REVIEW

2.1 Perspective of drought in Africa

Drought is the most common abiotic stress affecting plant growth and productivity in the world (Bohnet and Jensen, 1996). The effect of drought is more pronounced in the dry and sub-humid areas where rainfall is usually low, erratic and potential evapotranspiration is very high. The effect of drought on crop production can be minimized by growing cultivars that are resistant to water stress. Some of the crops that withstand moisture stress have growth duration that matches the rainfall duration (Tuinstra et al., 1996).

The drought tolerance is a phenotypic expression of a number of morphological and physiological mechanisms, including dehydration avoidance or tolerance (Ludlow 1993). Global warming models forecast that the average temperature in Africa could rise by up to 4°C over the next 100 years (IPCC, 2001). Its effect will include changing rainfall patterns and greater incidences of drought (Rowhani et al., 2011). Furthermore, it is predicted that by 2050 some regions will be 10 to 20 percent drier compared to the 1950-2000 averages (Kigotho, 2005); and hence the need for drought resilient crops.

Millions of people in some countries in Africa are at risk of reduced food security since over 95% of Africa's agriculture is rain-fed whose yields could be reduced by up to 50% by 2020 (www.unep.org/roa/amcen/docs). Owing to capacity of sorghum to produce some yield even in marginal environments, its importance as staple of choice in Africa will increase in arid and semi-arid tropics (Abdulai et al., 2012). In addition, sorghum also performs better under low soil fertility and other marginal environments compared to other locally grown crops (Ringo et al., 2010).

2.2 Importance of sorghum in Africa

In sub-Saharan Africa, over 100 million people depend on sorghum as staple crop (Frederiksen and Odvody, 2000). According to FAO (2010), Africa contributes over 60% to the total land area dedicated to cultivation of sorghum. Furthermore, demand for white sorghum in East Africa has increased dramatically after the East Africa Breweries Limited company started to use it for beer production (ICRISAT, 2013). Sorghum productivity in Eastern Africa has remained low (<1 t ha^{-1}) due to inadequate use of inputs, low yielding landraces and traditional farming practices (Aruna and Audilakshmi, 2008) that could mainly be attributed to scarcity of adapted cultivars.

Lately, sorghum has received significant attention because of its multiple uses as feed, and raw material in brewing and biofuel industries (Paterson, 2008). In Tanzania, over 800,000 tons of sorghum are produced annually by subsistence farmers, of which less than 2% of the harvest enters the formal market while the remainder is consumed at household level in form of a thin- and stiff porridge (Makindara et al., 2013). Report by Tanzania Ministry of Agriculture, Food Security and Cooperatives indicate that, annual demand for white sorghum is 3,360 metric tons while the supply in 2011/12 was only 1,084 metric tons indicating a significant difference between demand and supply (MAFSC, 2012).

In developing countries like the east African countries, poor and food-insecure people lives in semi arid areas. Moreover, semi-arid areas face a high risk of drought, which demand crops with a certain drought tolerance. Crops like sorghum are well adapted to both, the agroecological conditions of semi-arid areas and drought (FAO and ICRISAT, 1996). This makes them more resilient to production shocks as compared to maize. Moreover, sorghum can contribute to food security through its nutritional quality.

Sorghum has high calorie content and offers valuable nutritional ingredients including iron and zinc hence makes it competitive with maize (Koenders, 2010). In light of climatic change that is expected to lead to higher temperatures, more variable rainfall and extreme weather events will adversely affects agricultural production. The potential of sorghum to contribute to food security needs to be further explored (IPCC, 2014).

2.3 Major sorghum growing areas in East Africa

In the Eastern Africa region, the areas with high concentration of sorghum production include Central zone and around Lake Victoria in Tanzania; Northern and Eastern Uganda whereas in Kenya, sorghum is grown in Eastern, Nyanza and Coast Provinces (USAID, 2006). These areas are mainly characterized as dry lowlands and sub-humid agroecologies. The dry lowlands occupy about 2 million km^2 or 90% and 75% of Kenya and Tanzania respectively (FAO, 2010). The low level of precipitation and the high degree of variability limits the possibilities for rain fed crop production. More than 40% of these countries' population, live in dry lands (Hesse and MacGregor, 2006). The dry lands and sub- humid areas are characterized by low erratic rainfall of only up to 700 mm per annum, periodic droughts and different associations of vegetative cover and soils. The dry land areas receives annual rainfall of about 350 mm whereas sub-humid receive about 700 mm rainfall (USAID, 2006).

2.4 Sorghum Breeding in East Africa

Sorghum breeding in East Africa began with the collection and screening of local sorghum germplasm in Tanzania, Kenya and Uganda between 1930-1950 (Obilama, 2004). The focus of breeding at that time was for short season varieties, which resulted in the release of Serena variety in 1957 in Tanzania (Bantilan et al., 2004). In 1958, there was an establishment of East African Regional Sorghum Improvement Program at Serere in Uganda with the main focus on managing *striga* and bird damage. In 1978 two varieties, Seredo and Lulu-D, were released in Tanzania, Kenya and Uganda (Obilama, 2004).

The International Crop Research Institute for semi Arid Tropics (ICRISAT) started operating in the East African region in 1978 to assist in sorghum improvement. Their main focus was to select landraces as parents and perform adaptive testing of crossbreds (Bantilan et al., 2004).

Furthermore, the National Sorghum and Millet Improvement Program (NSMIP), in collaboration with the ICRISAT Sorghum and Millet Improvement Program (SMIP) developed improved sorghum varieties that mature early and give higher yields than landraces (Mgonja et al., 2005). The SMIP took major responsibility of providing improved germplasm to breeders in the region for testing, while National Agricultural Research Stations (NARS) breeders focused on multi-location evaluation of the germplasm, compiling and presenting the data to the national variety release committee. This led to the release of three sorghum varieties which includes *Tegemeo* (1986), *Pato* (1995), and *Macia* (1999). These were the first new releases in over a decade of concerted efforts to develop improved sorghum cultivars. By 2005, improved varieties of sorghum occupied approximately 36 percent of Tanzania’s sorghum area (Mgonja et al., 2005).

In recent years there has been remarkable effort and interventions by ICRISAT on sorghum research adoption particularly for dry land areas of east Africa. These efforts have been facilitated by other agricultural partners from various institutions in partner countries focusing on strengthening local seed systems and community-based seed production; and the national extension service to make farmers aware of the new varieties (Monyo et al., 2003). Through these efforts, ICRISAT has been introducing and making available new sorghum collections and inbred lines. All these genetic materials provide good starting point for hybrid sorghum production in East Africa region for increased yields.

2.5 Significance of hybrid sorghum in East Africa

Despite the fact that sorghum hybrids are better yielders than the open pollinated cultivars, there is no hybrids that are currently in use in Eastern Africa. Sorghum yield in the United States of America was similar to Africa’s in the 1960’s however, yield increased from 1.4 to >4.5 tha^{1} from 1960‘s due to deployment of hybrids coupled with improved agronomic practices (Jordaan et al., 1999).

Yield increase resulting from hybrid sorghum have been reported from various countries: for instance, grain yields of up to 6.2t ha^{-1} have been realized in Ethiopia

(Patil, 2007). In Niger, hybrid sorghum NAD-1 and ICSH and 89002NG in Nigeria have been commercially produced giving significantly higher yield over non-hybrid sorghum (House et al., 1997). In Sudan the sorghum hybrid Hageen Dura-1 was shown to out-yield local varieties by 50-85% on farmers' fields and 300-400% under irrigated conditions (Ejeta, 1986).

East Africa countries can achieve similar yield if suitable hybrids are developed and used. In this region, farmers are aware of the benefits of hybrid maize, and since sorghum is more adapted to semiarid environment where maize does not do well, it is very likely that farmers will also adopt sorghum hybrids. Moreover, the effect of climate change and emerging market in the brewing industry favour its production in the near future. Deployment of sorghum hybrids has a big potential to boost its production in the semi-arid and humid areas of East Africa.

It is important to evaluate yield stability of the potential parents for hybrid production across different environments due to the fact that development of sustainable sorghum hybrid program requires availability of locally adapted male parents. It is equally important to assess the fertility restoration ability of the potential parents and hybrids developed because both the genetic background and the environment in which the crop is grown influence this trait (Sleper and Poehlman, 2006). It is evident that high yielding and adapted sorghum hybrids can be developed and utilized in semi arid and humid areas of East Africa.

2.6 Hybrid production in Sorghum

2.6.1 Male Sterility and Hybrid Sorghum Production

Male sterility in sorghum results from incompatibility between nuclear and mitochondrial genes. It was identified from the interaction between sorghum race *kafir* nuclear genes with cytoplasm of race *milo* (Bantilan et al., 2004). Male sterility in sorghum is conferred either by recessive nuclear genes referred to genetic male sterility *(gms)*, or cytoplasmic factors regarded as cytoplasmic male sterility (*cms*). The sterility in *milo* cytoplasm is conferred by the homozygous recessive condition at one of the two loci ms_1ms_1 or ms_2ms_2, and is the one used in sorghum hybrid production (Sleper and Poehlman, 2006).

The nuclear and cytoplasmic genes involved in genetic control of cytoplasmic male sterility belong to genetic systems, which are strongly sensitive to environmental factors (Hanson and Bentolila, 2004). The *cms* is caused by expression of specific mitochondrial genes originating from high recombination activity peculiar to mitochondrial genome. However, expression of these genes takes place only in hybrid combinations, when they interact with foreign nuclear genomes (Yang et al., 2008).

2.6.2 Parental lines for developing hybrids

In sorghum hybrid production, three different lines (A-, B- and R-lines) are required. The A-lines lack fertility restoration (Rf_1) gene in their nucleus (Acquaah, 2007) and it is identical to its maintainer, the B- line that has the fertile cytoplasm. The B- lines are used to increase seed of A-line. The restorer, R-line carries dominant fertility restorer Rf_1 gene and therefore is used for hybrid seed production (Acquaah, 2007).

Sorghum hybrids are made by crossing A-lines to R-lines that restore fertility in the A-lines (Singh et al., 1997). Therefore, the cross between R- and A- lines forms F_1s which serve as experimental hybrids. The F_1s are then evaluated in replicated trials primarily at one or two locations followed by multilocational- testing of selected hybrids from this initial evaluation. Such activity allows establishing levels of heterosis (Hochholdinger and Hoecker, 2007) and combining ability (Tadesse et al., 2008; Vinaykumar et al., 2011). The multi-location evaluation allows selection of stable and adapted cultivars across environments (Bantilan et al., 2004).

The R-lines that flower 4-6 days later than the corresponding A-lines are preferred as the source of pollen for hybridization. Poor pollen shedders are usually not accepted. The difference in height between an R-line and an A-line should be about 30 cm for higher hybrid seed production (Singh et al., 1997). The seed setting ability of the hybrids should be >50%. Commercial sorghum hybrid seed is produced in large quantities by growing the designated A-line and R-lines together in a field, but ensuring 300m isolation distance (Murty et al., 1994).

2.6.3 Fertility Restoration in Hybrid Sorghum Program

Sorghum genotypes to be used as restorer lines must be tested to determine their restoration reaction (Singh et al., 1997) because their hybrids must possess a high level of fertility in order to produce a good crop. Consequently the ability to fully restore fertility is the most important character of a new line to be used in sorghum hybrid production. Fertility restoration is done by test-crossing the lines to a known *cms* line and observing the seed set on bagged progeny of the test cross.

The test hybrid with full seed set on all bagged panicles imply that the corresponding male parents are potential restorer lines for hybrid production. Male parents for which the test hybrid have partial seed set should be rejected from the breeding program as they neither serve as restorers nor maintainers. Test hybrid without seed set on all bagged panicles imply that the sterility was maintained in the hybrids and therefore can serve as a source of new A-lines.

The test hybrid with full seed set on some bagged panicles and non in others indicate that the parents are heterozygotes segregating for fertility restoration or sterility maintenance and hence should be discarded because they require fixing the genes (Singh et al., 1997). Male sterility and fertility restoration reactions can be altered by environmental conditions. High temperatures can lead to the breakdown of male sterility. Therefore, a high temperature environment is a good screening tool to ensure that only the best seed parents (A-lines) are retained. The converse applies for selection of good restorer lines (R-lines).

2.7 Properties used for selecting potential cultivars

2.7.1 Genetic diversity

The genetic diversity provides a practical yield benefit and resistance to adverse environmental conditions that explicate farmers to grow several crop varieties in their field (McNaught, 1988), and is also essential for developing new and high yielding varieties and hybrids of sorghum (Allard, 1999). Therefore genetic characterization has been based mostly on reliable morphological or agronomic, also known as phenotypic descriptors, which are easy to observe and evaluate (Mace et al., 2005).

Significant agronomic variations have been recorded for sorghums from different parts of Africa (Bucheyeki, 2006; Warkad et al. 2008). Phenotypic data can be used in identification of accessions and building a catalogue of descriptors with embedded biological information that is essential for collection, management or for use in agriculture (Hamon et al*.*, 2004).

The disparity of the agroecologies in which sorghum is cultivated in East Africa indicates that there should exist significant genetic differences among the sorghum genotypes that could be exploited for yield improvement. It is therefore beneficial to phenotype these differences and use the knowledge in breeding to fill the current yields and stress tolerance gaps. Moreover, identification and documentation of variability in agronomic traits for sorghum genotypes is important because such information facilitate conservation process and also use in breeding programs. Plant characterization has been done mostly on morphological or agronomic descriptors because they do not depend upon expensive, sophisticated equipment (Mace et al., 2005).

Characterization of morphological traits in crops such as sorghum can achieved at relatively low cost and the information is potential for selection and breeding purposes. Rao et al. (1998) employed agronomic characters of 152 sorghum genotypes from Rwanda and ICRISAT and showed significant variability in sorghum genotypes. Amsalu and Endashaw (2000) also used morphological characters to determine the genetic variations of 415 sorghum genotypes from Ethiopia and Eritrea. Using similar approach, Sallu (2007) reported wide genetic variations among sorghum collections in Tanzania gene bank. Warkad et al. (2008) reported significant variations in sorghum yield and yield components particularly plant height, number of leaves, days to 50% flowering days to maturity, dry fodder weight, panicle length and width, and yield. Kolberg (1999) reported substantial morphological variations for agronomic traits in 124 sorghum genotypes from Namibia.

2.7.2 Genotype-by-Environment (G×E) interaction

Success of genetic enhancement programs depend on identification of genotypes adapted to specific season with stable performance for harnessing maximum gains from the selection. The measured yield of each cultivar in each test environment is a measure of an environment main effect (E), a genotype main effect (G), and the genotype × environment (GE) interaction (Yan and Tinker 2005). In many cases, E explains 80% or higher of the total yield variation; nevertheless, it is G and GE that are relevant to cultivar evaluation (Yan et al. 2002). The GE interaction reduces the correlation between phenotype and genotype and selection progress.

In many crop breeding programs, performance of trials are conducted in multiple environments because the performance of a genotype can vary with environment; a condition termed genotype-by-environment interaction. To be able to visualize the interrelationship among environments, genotypes, and interactions between genotypes and environments, genotype and genotype-by-environment (GGE) biplot analysis has been commonly used (Yan et al. 2000). Usually a large number of genotypes are tested across a number of sites and seasons and it is often difficult to determine the pattern of genotypic response across locations or seasons without the help of graphical display of the data (Yan et al. 2001). Biplot analysis, provides solution to the above problem as it displays the two-way data that can be clearly visualized.

The GGE biplot analysis is based on environment-centered principal component analysis (PCA) (Yan and Tinker, 2005). The GGE biplot technique helps to identify the possible existence of different mega-environments of a particular crop along various growing regions and facilitates determination of discriminating ability and representativeness of the environments (Yan et al. 2000). The GGE biplot has been used to identify high yielding and adapted sorghum cultivars by many researchers as reported by Srinivasa et al. (2011).

2.7.3 Heritability and genetic advancement

Success in crop improvement program depends on amount of variability available and its utilization. In any breeding program, selection for yield is one of the most important and difficult challenge. Individual yield components might contribute valuable information in breeding for yield. Increase in yield levels are difficult to be obtained thus evaluation of individual yield components provides a better basis for progeny evaluation than yield itself.

Knowledge of the extent to which the desirable characters are heritable is a prerequisite for any crop improvement program, especially for sorghum hybrid development (Jain and Patel, 2012). The amount of genetic variability available in sorghum for yield and contributing traits is useful for developing high yielding genotypes. The heritable variation is useful for genetic improvement in crops including sorghum (Singh, 2000). The most important function of the heritability is its predictive role to indicate the reliability of the phenotypic value as a guide to breeding value (Falconer and Mackay, 1996).

The genotypic coefficient of variation along with heritability estimates provide reliable estimates of the amount of genetic advance to be expected through phenotypic selection (Warkard et al., 2008). Furthermore, heritability and genetic gain are among important selection criteria in crop breeding because they facilitate understanding of the type of gene action involved in the expression of the particular traits (Kang et al., 1983). High values of genetic gain indicate effect of additive gene action whereas low values are indicative of non-additive gene action (Singh and Narayanan, 1993). Therefore, improvement of a crop depends on the degree of variability in the desired character in the germplasm collections (Jain and Patel, 2012).

Furthermore, to determine relationships, correlation analyses are used such that the values of two characters are analyzed on a paired basis, results of which may be either positive or negative. When there is positive association of major yield trait the breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety (Kang et al., 1983).

In this study, sorghum lines from ICRISAT-Nairobi collection were used to assess levels of genetic variability and selection response in selected sub humid and dry low land agroecologies of east Africa. The study of relationships among yield traits is important for assessing the feasibility of selection of two or more traits and hence for evaluating the effect of selection for secondary traits on genetic gain for the primary trait under consideration. A positive genetic correlation between two desirable traits facilitates improving both traits simultaneously. Crop improvement depends largely on phenotypic and genotypic variances, phenotypic and genotypic coefficient of variation (PCV and GCV) and broad sense heritability (Warkard et al., 2008). The extent of variability is measured by genotypic coefficient of variance (GCV) and phenotypic coefficient of variance (PCV) which provides information about relative amount of variation in different characters (Geleta et al., 2005).

2.7.4 Heterosis as a measure for selecting superior parental lines

Potential of sorghum hybrids is estimated from the percentage increase or decrease of their performance over the mid parent (average heterosis) and better parent (heterobeltiosis) (Hochholdinger and Hoecker, 2007). According to Lamkey and Edwards, (1999), heterobeltiosis is more realistic and practicable because it shows the performance of the hybrid in comparison with the best parent unlike mid-parent heterosis that compares the hybrid with the mean of the two parents. Nevertheless, the mid parent and better parent heterosis provides information on genetic diversity of parents in developing superior F1s therefore possibility to exploit hybrid vigour.

Heterosis has been confirmed in sorghum, rice and maize (Liu et al., 2014). For the case of this study, average heterosis and heterobeltiosis were determined in order to identify parental lines to develop hybrids sorghum that would be adapted in dry lands and sub-humid environments. Positive average heterosis and heterobeltiosis in a desired trend is preferred in selection for yield and its components (Lamkey and Edwards, 1999). Furthermore, selection of superior parents for outstanding hybrids depend much on effects of heterosis and heterobeltiosis as also reported by Reif et al. (2007). Identification, hence utilization of highly productive hybrids can significantly raise production and improve food security in the East African countries as supported by the success stories from Ethiopia (Patil, 2007), Sudan (Ejeta, 1986) and Niger and Nigeria (House et al., 1997).

Using appropriate selection of parental lines, it is possible to develop superior hybrids sorghum adapted to East African conditions. Among the objectives of this study was to determine the levels of heterosis and heterobeltiosis for yield and yield components by identifying suitable heterotic parents for hybrid sorghum breeding program in East Africa. Ordas (1991) showed that the amount of heterosis in a maize hybrid was directly proportional to the genetic divergence of the parents from which the inbreds lines have been extracted; the more divergent parents are, the higher is the heterosis. Positive or negative heterosis in a desired direction is preferred in selection for yield and its components (Lamkey and Edwards, 1999). Selection of superior parents for outstanding hybrids depend much on heterosis and heterobeltiosis and both are influenced by non-additive gene action (Reif et al., 2007).

2.7.5 Combining ability in crop improvement

Combining ability is the capacity of a line to produce good hybrids in combination with male sterile lines. A line with good general combining ability will tend to give high yielding hybrids with many male sterile parents (Acquaah, 2007). The combining ability in sorghum is very closely associated with *per se* performance of the line (Tadesse et al., 2008). Furthermore, both general combining ability (GCA) which is an average performance of an individual in a particular series of hybrid and specific combining ability (SCA) which is a performance of a parent under consideration, in a specific cross effects are important in many sorghum traits including grain yield (Tadesse et al. (2008).

Knowledge of GCA and SCA attributes of breeding lines is important when assessing their suitability in hybrid development since these parameters reflect true genotypic value of a breeding line (Sigh et al., 1997). There is generally a direct positive correlation between the combining ability of a line and the average performance of its hybrid (Reddy et al., 2007). The GCA gives an indication of the concentration of predominant genes with additive effects and low GCA whether positive or negative, indicates that the mean of a parent in crossing with the other, is relatively similar to the general mean of the hybrid (Kenga et al., 2004). Therefore sustainable sorghum hybrid program requires availability of locally adapted parental lines.

The International Crops Research Institute for Semi Arid Tropics (ICRISAT) introduced new inbred lines from India and collections from various parts of East Africa but their combing ability has not been studied. Information on general combining ability (GCA) and specific combing ability (SCA) is vital to start a hybrid program. Therefore among the specific objectives of this study was to identify the best hybrids and their parents through determination of GCA and SCA for yield and yield components of a comprehensive set of introduced inbred lines for sub-humid and dry low-lands of East Africa.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Experimental Sites

The experiments were conducted at Kiboko (Kenya), and Miwaleni and Ukiriguru (Tanzania) which represent the major sorghum growing agroecologies. Because all the experimental sites are within Agricultural Research Stations the soils and weather data have been collected and is accessible. Kiboko site is located 37°45'E, 2°15'S, and 960 m above sea level (asl). It is a semi-arid agro-ecology receiving about 655 mm of rainfall annually (www.kari.org). The mean minimum and maximum temperature is 13.7^{o}C and 24.7^{o}C, respectively. The soil type at this station is sandy clay.

Ukiriguru site is in sub-humid agro-ecology (ILCA, 1987) and is located 2° 43' 0" S and 33° 1' 0" E and 1198 m asl. The temperature ranges from 18.3°C to 29.6°C. Ukiriguru experiences a bimodal rainfall pattern; the long rains is from March to May whereas the short rains fall from October to December. The annual mean annual rainfall at this station is 861mm. The cool dry season is from June to August and experiences low temperatures which range between 11°C and 20°C (Tungaraza et al., 2012). The soil type at this station is sandy loam (ILCA, 1987).

Miwaleni site is located at 3° 25' 30" S and 37° 26' 45" E, and 720 m asl. This station is typical of the lowland with a semi arid climate receiving an annual rainfall of about 659 mm/yr (John, 2010). The temperatures range between 39°C during dry seasons to 10°C during wet season and the soil type at this station is clay loam (FAO, 2007).

3.2 Genetic diversity of sorghum genotypes using morphological markers

This experiment involved evaluation of 121 parents that included elite lines, commercially released varieties and landraces all acquired from ICRISAT. In all experiments, *Macia* a commercially released variety was used as a check due to its high yielding and popularity in the eastern and southern Africa region. This experiment was planted in an alpha lattice design with three replications during 2011 and 2012 growing seasons at Kiboko, Miwaleni and Ukiriguru. Each genotype was grown in a 4 m long row at spacing of 60 cm between rows and 50 cm within row. A basal fertilizer application of 20 kg ha^{-1} (N/ha), and 20 kg ha^{-1} (P/ha) was applied at sowing in all experiments (as per general ICRISAT recommendations). Thinning was done two weeks after emergence to 2 plants per hill. Four weeks after emergence, an additional 45 kg ha^{-1} N, in form of urea, was top-dressed and other agronomic practices including weeding and disease control was followed as per requirements.

Five plants that were randomly selected and tagged in the 6th week after emergence using the standard sorghum descriptors (IPGRI, 1993) and used for data collection. Data was collected for days to 50% flowering (DAF), plant height (HT) in cm, panicle length (PL) in cm, panicle width (PW) in cm, panicle (PE) in cm, panicle shape (PS), number of tillers per plant (TL), seed setting capacity (SS) in percentage, plant colour (PC), grain colour (GC), awns at maturity (AW), and grain yield (Y) in t/ha, disease and pests score. The DAF was used as an estimate to maturity status of sorghum materials used in this study.

The data was analyzed using (SAS, 2008) in two ways. The data from lattice designs were analyzed separately for each environment and then a combined analysis over environments. Effects or differences were accepted as significant at $p \leq 0.05$. Combined analysis of variance was done for each environment according to Gomez and Gomez (1984).

3.3 Development and testing the experimental hybrid sorghum

A total of 36 pairs of male sterile lines (A, B lines) and 27 restorers (R-lines) were obtained from ICRISAT-Nairobi (Appendix 1) for evaluation and generating experimental hybrids. Production of the hybrids was conducted at Kiboko in 2010 under irrigation. Seed for all parents was hand planted in 2-m rows. Two rows of A-lines were grown parallel to 1 row of B-lines (for maintenance of A-lines and data collection on yield alongside a block of R-lines. Each R- line occupied a single row.

All plants were bagged just before flowering to avoid cross pollination. Pollen was collected in paper bags from R-lines in the morning hours (before 11:00 am) and dusted on to female panicles. Each single head of A-line was pollinated by single R-line and both bagged right after pollination. A total of 415 experimental hybrids were generated.

The F_1 hybrid seed were harvested but only 353 had enough seed for testing restoration capacity in two locations. The fertility restoration capacity of the restorer lines was tested in the 2010 long rain season at Kiboko and Miwaleni. The hybrids were sowed in single, 4-m rows with 60 cm between rows and 50 cm between plants.

Five plants from each entry were bagged with pollination bags before flowering to determine the fertility status of the hybrid. Pollination bags were removed at the soft dough stage and the seed set on bagged heads was assessed visually using a scale of 0% to 100%; where 0% represented a completely sterile head without seed set, and 100% represented a completely fertile head with complete seed set as illustrated in Appendix 2.

Other phenotypic data on days to 50% flowering, % seed set on the bagged panicles and grain yield was collected using Sorghum Descriptors (IPGRI, 1993) on the five plants that were randomly selected and bagged before flowering.

3.4 Heritability and genetic gain of the sorghum lines

The genetic variability was calculated as described by Steel and Torrie (1980). The broad sense heritability (H) was estimated for each trait according to Falconer, (1989), using the equation:

$$H = \frac{\delta^2 g}{\delta^2 p} \qquad \text{[Eq. 1]}$$

Where: $\delta^2 g$ = genotypic variance and $\delta^2 p$= phenotypic variance

The $\delta^2 g$ and $\delta^2 p$ were computed according to Comstock and Robinson (1952). The mean values were used to calculate the genetic coefficient of variation (GCV %) and phenotypic coefficient of variation (PCV%) according to Burton and De Vane (1953) as:

$$\mathrm{GCV\%} = \frac{\sqrt{\delta^2 g}}{\mu} \times 100 \qquad \text{[Eq. 2]}$$

$$\mathrm{PCV\%} = \frac{\sqrt{\delta^2 p}}{\mu} \times 100 \qquad \text{[Eq. 3]}$$

Where: μ = grand mean.

The genetic gain (GG) of selecting superior genotypes at 5% intensity of selection pressure was calculated according to Singh and Chaudhary (1985) as:

$$GG = k \times s\delta^2 \mathrm{p} \times \mathrm{H} \qquad \text{[Eq. 4]}$$

Where: GG = genetic gain; *k* = constant = 2.06 (Kang et al., 1983);
$s\delta^2\mathrm{p}$ = square root of phenotypic variance

H = Broad sense heritability

Expected genetic gain (EGG) as % of mean was computed from the equation

$$\mathrm{EGG} = \frac{\sqrt{GG}}{\mu} \times 100 \qquad \text{[Eq. 5]}$$

3.5 General and Specific combining ability of the sorghum genotypes

Line × Tester analysis was carried out for each trait for individual environments. To have an overall understanding, the data was analyzed over all environments jointly. The general combining ability (GCA) and specific combining ability (SCA) effects were computed from the Line × Tester analysis. The GCA effects for the parents were calculated according to Kearsey and Pooni (1996) whereby:-

$$GCA_f = X_f - \mu \qquad \text{[Eq. 6]}$$

$$GCA_m = X_m - \mu \qquad \text{[Eq. 7]}$$

Where: X_f, X_m = mean performance of female and male lines respectively;

GCA_f and GCA_m= GCA for female and male parents respectively;

μ = grand mean.

$$SCA_X = X_x - E(X_x) = X_x - GCA_f + GCA_m + \mu \qquad \text{[Eq. 8]}$$

where: SCA_X = SCA effects of the two parents in the cross; X_x= observed mean value of the cross; $E(X_x)$= expected value of the cross basing on the GCA effects of the two parents;

GCA_f and GCA_m= GCA for female and male parents respectively

μ = grand mean of the hybrid.

The ranking for parental combination basing on combining ability was obtained by taking combining ability effects as significant positive (high), non-significant (average) and significant negative (low). In addition, for days to 50% flowering and plant height traits, the significant positive combining ability effects is taken as low, non-significant as average and significant negative as high.

3.6 Heterosis of the hybrids based on yield and yield components of the hybrids

The mid parent heterosis (*Hmp*) and Heterobeltiosis, (*Hbp*) were computed according to Alam et al.(2004) as follows:-

$$H_{mp} = \frac{X_x - X_{mp}}{Xmp} \times 100 \qquad \text{[Eq. 9]}$$

and

$$H_{bp} = \frac{X_x - X_{bp}}{Xbp} \times 100 \qquad \text{[Eq.10]}$$

where:- H_{mp} and H_{bp} = mid parent and better parent heterosis respectively

X_x = observed mean value of the cross

X_{mp} = mean of the mid parent

X_{bp} = mean of the better parent.

3.7 Stability and adaptation of hybrids and their parents

The data analyses for interpreting GE interaction and GGE biplot were performed using GenStat, (2012) software. The partitioning and interpretation of genotype main effect (G) and GE interaction were based on GGE biplot that was constructed using first two principal components (PCA1 and PCA2). The two principal components were derived from subjecting the environment-centred data to singular-value decomposition. Additionally, the GGE biplot method was used to visually identify the stability of the hybrids and parental lines across test environments.

CHAPTER FOUR

RESULTS

4.1 Experimental sites

Data on mean temperature, rainfall and relative humidity from three test locations are presented in figures 1, 2 and 3 respectively. In general, Ukiriguru location experienced high relative humidity (77 - 79%) and temperatures (18.4 – 29.3^{o}C) especially during flowering (February). The mean monthly rainfall was lower (102mm average) during the same period. Miwaleni location was characterised by relatively higher monthly rainfall (average of 156.2mm), low temperatures (17.3 – 24.4^{o}C) and low relative humidity (54-66.3%) during flowering (March). Kiboko experienced similar conditions to Miwaleni except that rainfall was relatively lower (114mm) in March.

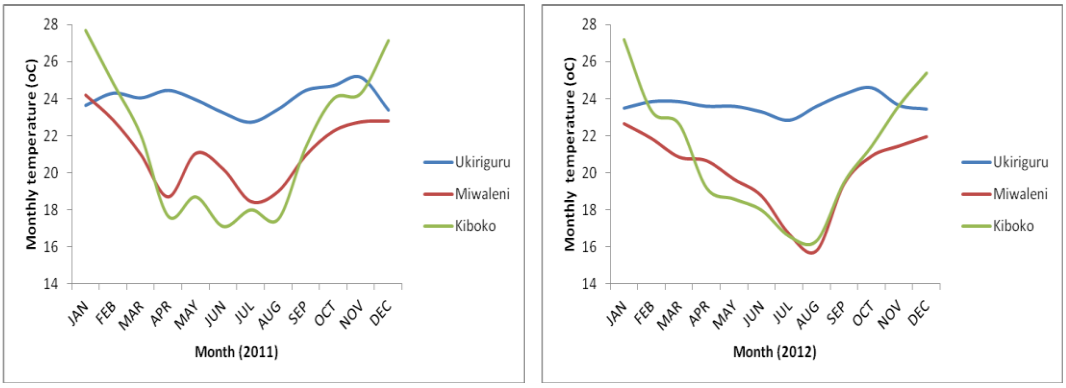


Figure 1: Mean monthly temperatures in ^{o}C for Ukiriguru, Miwaleni and Kiboko during 2011/12 seasons

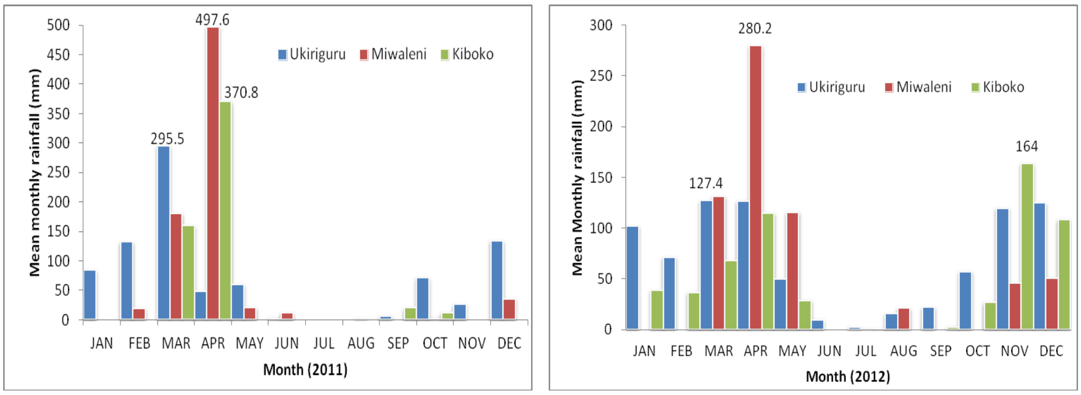


Figure 2: Mean monthly rainfall (mm) for Ukiriguru, Miwaleni and Kiboko during 2011/2012 seasons

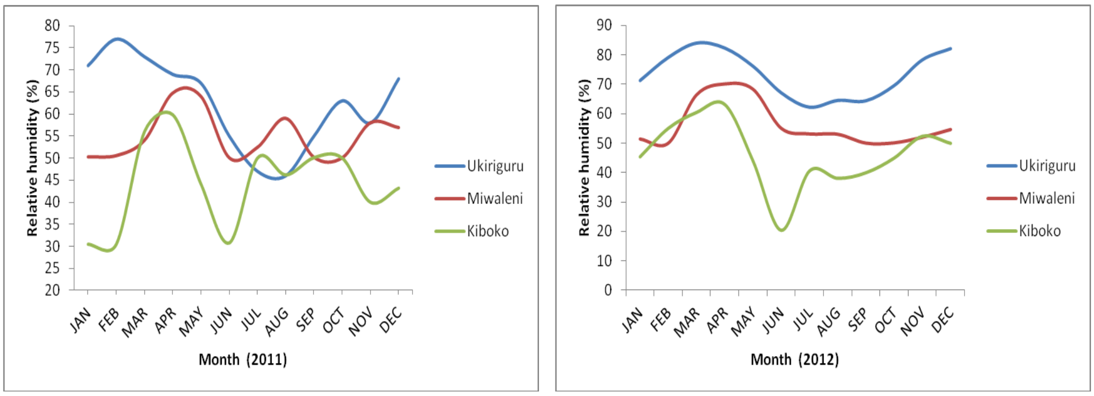


Figure 3: Mean relative humidity in % for Ukiriguru, Miwaleni and Kiboko during 2011/2012 seasons

4.2 Genetic diversity of sorghum genotypes using morphological markers

There was significant ($p \leq 0.05$) phenotypic variations among environments, female lines and hybrids for days to 50% flowering (DAF), tillers per plant (TL), plant height (HT), panicle (PE), panicle length (PL), panicle width (PW), percent seed setting (SS), panicle shape (PS), agronomic score (AS), grain color (GC), plant color (PC) and yield (GY) across all locations (Table 1).

It was interesting to note that male lines (R-lines) were significantly ($p \leq 0.05$) for all traits except number of tillers and plant colour. Results indicate that the interaction, Female × Male did not show significant differences for DAF, HT, PE and AS across test environments.

The interaction environment × hybrids expressed significant differences for all traits except on TL, PW, AS and GY. Moreover, environment × female parents was not significant for PW, AS and GY. The interaction environment × male parents expressed significant differences in other agronomic traits except for DAF, TL, PE, PW, AS and GY.

Three way interaction, Environment × Female × Male had no significant differences for many agronomic traits including DAF, PE, PW,PL, SS, AS and yield.

Table 1: Mean squares of agronomic traits evaluated in sorghum genotypes during 2011/2012 growing seasons at Kiboko, Miwaleni and Ukiriguru

SOURCE	DF	DAF	TL	HT	PE	PL	PW	%SS	PS	AS	GC	PC	GY
Environment (Env)	2	2382.2*	468.8*	179447.7*	3861.2*	2839.2*	962.6*	14182.2*	447.7*	21.2*	228.9	0.7*	111459.7*
Replications	2	9.0	12.8	2165.8	60.0	30.5	18.6	1260.8	2.44	2.3	1.8	0.1	6413.2
Hybrids	92	56.5*	3.2*	5316.3*	90.3*	49.5*	9.6*	7321.5*	3.24*	1.4*	1.4*	0.1*	1700.6*
Female lines	27	157.0*	5.7*	6714.1*	211.6*	106.1*	18.4*	489.2*	4.3*	2.6*	1.6*	0.2*	1933.9*
Male lines	45	18.7*	2.0	7540.4*	45.3*	35.2*	6.9*	642.1*	3.6*	1.2*	1.9*	0.1	1587.2*
Females×Males	26	8.91	2.5*	528.6	31.7	12.4*	4.4*	176.4*	1.6*	0.4	0.6*	0.1	1628.6*
Env×Hybrids	184	13.3*	2.9	616.1*	26.7*	8.2*	3.4	126.8*	1.7*	0.7	2.1*	0.6*	785.2
Env×Females	54	19.1*	4.8*	720.3*	45.7*	10.6*	5.3	221.3*	2.3*	0.8	3.3*	1.5*	883.4
Env×Males	78	11.1	1.96	550.6*	17.1	8.8*	2.9	142.1*	1.7*	0.8	2.3*	0.3*	721.6
Env×Females×Males	52	10.8	2.4*	606.2*	21.4	4.8	2.1	192.3	1.2*	0.6	0.5*	0.1	778.5
Error	420	5.65	0.9	221.9	11.6	4.7	1.5	78.2	0.6	0.5	0.2	0.1	580.6

Note: * significant at p≤ 0.05; DAF = Days to 50% flowering; HT= Plant height (cm); PC= Plant color; TL= Basal tillers; PS= Panicle shape; PE = Panicle (cm); PL = Panicle length (cm); PW= Panicle width; %SS = seed set (%); PS = pest score; AS= Agronomic score; GC= Grain color; GY = Grain yield per panicle (g); Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

4.2.1 Grain yield performance of sorghum parental lines in three locations

The results for the best ten parents compared to local check variety (*Macia*) is shown in Table 2 but overall performance is presented in Appendix 3. The highest grain yield of 3.5 t/ha was recorded in ICSR93034, while the check yielded 2.3t/ha. The same genotype took relatively longer time (about 4 more days) to attain 50% flowering compared to the check variety. The lowest grain yielder was SP74276 (0.3 t/ha). The overall mean yield for the genotypes was 1.9 t/ha. In overall sorghum genotypes took 69 days to attain 50% flowering. The sorghum materials grew to an average height of 162.4 m. Among the best 10 parental lines, IESV 23008 DL was the earliest to attain 50% flowering (66 days) while ICSR24007 was the latest (75.2 days); the check variety took 68.4 days to 50% flowering.

Table 2: Grain yield performance of the best ten parents at Kiboko, Miwaleni and Ukiriguru during 2011/2012 season

No	GENOTYPE	DAF	HT	PC	TL	PS	PE	PL	PW	AW	Y(t/h)
1	ICSR 93034	73	141.3	1	0	6	3.9	30.3	8.5	0	**3.5**
2	KARIMTAMA1	69	173.1	1	0	5	12.8	31.8	7.9	0	3.3
3	ICSR 89028	69	209.4	1	0	6	3.2	26.6	8.2	0	3.1
4	IESV 91104 DL	69	194.8	1	0	6	4.8	23.6	8.1	0	3.1
5	ICSV 574	74	204.4	1	0	6	2.1	23.3	7.9	0	2.9
6	IESV 23008 DL	**66**	151.2	1	0	6	3.8	23.9	7.5	0	2.8
7	ICSR 160	71	159.3	1	0	5	3.2	28.3	7.5	0	2.8
8	IESV 23011 DL	69	185.9	2	0	6	7.4	31.1	8.8	1	2.7
9	ICSB276	67	168.6	1	0	6	4.0	24.7	7.9	0	2.7
10	ICSR 24007	75	130.7	1	0	7	3.6	26.7	6.5	0	2.7
11	*MACIA* (check)	68	125.1	1	0	6	4.3	25.5	7.1	0	**2.3**

DAF = Days to 50% flowering; HT= Plant height (cm); PC= Plant color; TL= Number of tillers; PS= Panicle shape; PE = Panicle exertion (cm); PL = Panicle length (cm); AW= awns at maturity; Y = Grain yield (t/ha): Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

Chitichi was the earliest sorghum in all locations and took an average of 54.3 days to attain 50% days to flowering; whereas Busia#38-Sabina was the latest at 76 days to flowering. The other early maturing lines included ZSV3, S35, IESV23010DL and ICSV95023. There was significant variation ($p \leq 0.05$) in height among the test sorghums: the tallest line was IS 11167, whereas the shortest was MB6. Also, ICSR37 and IESV91131DL were among the shortest materials identified in this study. A total of 25 out of 27 (92.6%) of the A-lines studied did not produce tillers. Only one male sterile line, ICSB686 produced an average of 1 tiller per plant across the agroecologies. Restorer lines TESO#15-3 and TESO#17 (Etoroit) had the highest (3) number of tillers per plant.

About 64% of sorghums studied developed tan shoots whereas 36.2% had purple shoots. Sorghum lines exhibited significant different panicle shapes (Figure 4); including semi-loose drooping primary branches (53 entries) semi loose erect primary branches (21 entries), loose drooping primary branches (13 entries) and semi compact elliptic panicles (7 entries).

(i) Makueni local (ii) IESV 95046 (iii) ICSV 189 (iv) SIAYA # 46-1

Figure 4: Panicle shapes of test genotypes: (i) Semi loose drooping primary branches (ii) Semi compact elliptic- (iii) Compact oval (iv) Compact elliptic

(Source: Author, 2015)

Panicle varied from 0.6 cm (IESB2) to 14.8cm (B2DN55). The panicle length varied from 10.7cm (IS 8884) to 32.9 ICSB12; and for the panicle width, MB6 had very small panicles measuring 5.2cm while ICSV95046 had the broadest panicle measured 10cm. A majority of the accessions did not posses awns; only four genotypes, ICSB479, ICSB686, IESV23011DL and IESV23019DL expressed awns at maturity. In addition, large proportion (60%) of the materials evaluated were white seeded whereas 38% were brown and only 2% had red seed. Results from individual locations are presented in Appendices 4,5, and 6 for Ukiriguru, Kiboko and Miwaleni, respectively. There were significant differences for grain yield and important yield traits such as days to flowering and plant height. The DAF varied from 68 to 73 days between the test locations. Moreover, the plant height varied significantly from 147cm to 162cm whereas yield varied from 2.6t/ha to 5 t/ha.

Overall performance at Ukiriguru indicate that sorghum genotypes took an average of 73 days to reach 50% flowering. The average height for the genotypes was 147.1cm tall whereas the yield averaged 1.9t/ha. However, the highest and significant grain yield at Ukiriguru was recorded for KARI MTAMA 1 (4.3 t/ha) and IESV 23019 (3.8t/ha) while the lowest yielder at this environment was Siaya #42. (1.2 t/ha).

The performance of the best ten parents at Ukiriguru is shown on Table 3 whereas the overall results is presented in Appendix 4. In general, the sorghum inbred lines performed higher than the landraces at Ukiriguru. Nine out of the best ten sorghum materials identified are inbred lines and one which is KARI MTAMA 1 is commercially released variety in Kenya.

Table 3: Performance of top 10 sorghum parents at Ukiriguru basing on grain yield

No	Genotype	DAF	HT(cm)	TL	PS	Y (t/ha)
1	KARI MTAMA 1	68	202.1	0	6	4.3
2	IESV 23019	74	116.1	1	6	3.8
3	ICSR93034	71	140.1	0	6	3.5
5	IESV91104 DL	67	112.8	1	5	3.3
6	ICSR 162	78	193.5	2	6	3.1
4	IESV 23014 DL	77	113.7	2	6	3.0
7	IESV 23007 DL	73	148.0	2	6	3.0
8	ICSB 88006	72	116.7	2	6	3.0
9	ICSB 88001	77	142.7	1	6	3.0
10	ICSB 366	70	129.6	2	6	3.0
11	*Macia* (check)	72	120.7	0	6	2.2

Note: DAF = Days to 50% flowering; HT= Plant height (cm); TL= Number of tillers; PS= Panicle shape; Y = Grain yield (t/ha). Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

The ten (10) highest yielding lines at Kiboko are presented in Table 4 and the overall and detailed performance is presented in Appendix 5. The overall mean grain yield at this location was 2.2 t/ha. It was interesting to note that one local collection, SIAYA # 97-1 yielded higher 3t/ha but was late (75 DAF) than the check which yielded 2t/ha and took 68 days to attain 50% flowering. The least yielder at this location was MB6 that produced only 1.4t/ha.

Compared to check variety, all best selected lines were relatively taller though high yielding. In terms of tillering, majority of the evaluated lines did not tiller. Also, awns at maturity trait was rarely found in some genotypes. The restorer lines ICSV 95022, IESV 23011 DL and IESV 91104 DL performed relatively similar in terms of days to 50% flowering, plant height, tillering, panicle shape and grain yield.

Table 4: Performance for yield and associated traits of the top 10 parents and check variety at Kiboko site during 2011-2012 season

No	Genotype	DAF	HT	TL	PS	Y (t/ha)
1	SIAYA # 97-1	75	270.7	1	7	3.0
2	ICSB 276	69	173.1	0	5	2.8
3	ICSR 93034	70	209.4	0	7	2.8
4	ICSR 89028	73	141.3	0	7	2.7
5	KARIMTAMA1	68	168.6	0	6	2.7
6	ICSR 89001	74	128.5	0	6	2.6
7	ICSV 95022	69	131.8	0	6	2.6
8	IESV 23011 DL	69	185.9	0	6	2.6
9	IESV 94104 DL	66	151.2	0	6	2.6
10	ICSB 592	71	169.7	0	6	2.5
11	*Macia* (Check)	68	124.3	0	6	2.0

Note: DAF = Days to 50% flowering; HT= Plant height (cm); TL= Number of tillers; PS= Panicle shape; Y = Grain yield (t/ha). Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

Ten (10) highest yielder parent at Miwaleni are presented on table 5 but overall performance of the materials is reported in Appendix 6. The best yielder at this location was ICSB 683 that produced 3.7t/ha higher than the check variety that produced 2.9t/ha. The same inbred line ICSB 683 was very early (64 DAF) and was also short in stature (118.4 cm) compared to an overall mean of 159 cm. However, all best ten parental lines yielded higher than the check variety. The least yielder at this environment was ICSR 93001 that produced 1.7t/ha. majority of evaluated genotypes at Miwaleni developed panicles with semi compact elliptic shape (panicle shape 6)

Table 5: Grain yield and associated traits for the top 10 parental lines selected at Miwaleni

No	**Genotype**	**DAF**	**PH**	**TL**	**PS**	**Y (t/ha)**
1	ICSB 683	64	118.4	0	6	3.7
2	ICSR 89068	68	174.1	0	6	3.6
3	ICSR 89059	75	143.9	0	6	3.5
4	KARI MTAMA 1	63	166.3	0	6	3.5
5	IESV 91104 DL	61	185.9	0	6	3.4
6	SDSB 29	72	141.2	0	6	3.4
7	SIAYA # 42	70	171.9	2	7	3.3
8	SP 74276	66	136.7	0	6	3.2
9	BTX 623	67	120.1	0	6	3.0
10	ICSR 93034	66	196.0	0	6	3.0
11	Macia (check)	65	129.6	0	6	2.9

Note: DAF = Days to 50% flowering; HT= Plant height (cm); TL= Number of tillers; PS= Panicle shape; Y = Grain yield (t/ha). Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

4.3 Performance of the sorghum hybrids in Kiboko, Miwaleni and Ukiriguru

The summary of fertility restoration for the test hybrids is presented in Table 6 for Kiboko and Miwaleni but the detailed information is given in Appendix 7. There was remarkable difference in seed setting among the hybrids (Figure 5). Out of 313 tested hybrids, (93%) exhibited more than 80% seed set, with Kiboko registering higher values than Miwaleni. Only 110 (32%) of the hybrids had 100% restoration; among those, 64 were at Kiboko, and 46 at Miwaleni. One hundred and twenty (120) hybrids (35.6%) did not produce seed at all in the bagged panicles in both locations.

Table 6: Fertility restorations of hybrids at Kiboko and Miwaleni in 2011

Seed set (%) Range	Number of hybrids Kiboko	Number of hybrids Miwaleni	Total	% Hybrids
100	64	46	110	32.6
80 to <100	166	147	313	92.9
60 to <80	2	28	30	8.9
40 to <60	12	11	23	6.8
20 to <40	4	23	27	8.0
1 to <20	17	34	51	15.1
0	72	48	120	35.6

Note: seed set percent range adopted from sorghum descriptors (IPGRI, 1993)

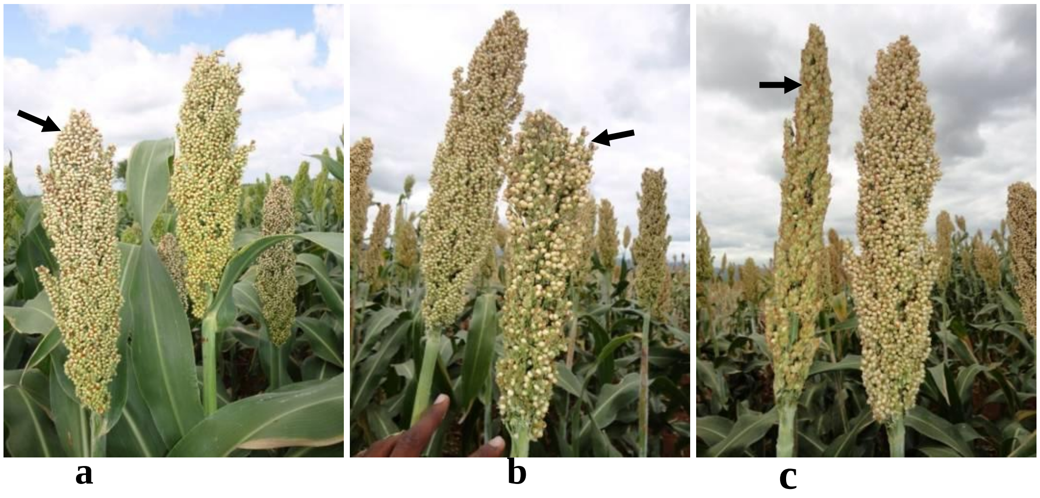


Figure 5: Fertility status of some hybrids tested at Kiboko and Miwaleni (a) fully restored (b) partially restored (c) extremely low restoration on bagged panicles indicated by arrows.

(Source: Author, 2015)

Some hybrids expressed full seed set in a number of bagged panicles but not others within and across the sites as presented in Appendix 7. However, some female lines such A_2DN_{55}, ICSA479, ICSA469, consistently produced poor hybrids in terms of seed set irrespective of male parent used. A total of 171 hybrids were within the recommended fertility restoration range of 80% to 100%, for multi-location advanced trials (Appendix 1). These hybrids also possessed high yield of up to about 6 t/ha and took between 66 days to reach 50% flowering. However, only 118 out of 353 hybrids had enough seed for multi-location hybrid trials across three locations.

The earliest hybrid (ICSA366 × KARI MTAMA1) attained 50% flowering in about 59 days; the same cross was also the earliest at Miwaleni and took 52 days to reach 50% flowering. MA6 × ZSV3 was the earliest at Kiboko taking 59 days. The hybrid ICSA469 × IESV23011DL took longest time to reach 50% flowering at Miwaleni.

The overall highest yielding hybrids from all the locations was ICSA89003 × Siaya# 27-3. The hybrids ICSA371 × IESV23008 DL and ICSA 469 × SP74276 were the best yielders at Miwaleni and Kiboko respectively. The lowest yielders were ICSA469 × ICSV574 and ICSA376 × TEGEMEO at Kiboko and Miwaleni respectively.

4.3.1 General performance of the sorghum hybrids

Performance of the hybrids basing on Days to 50% flowering, percent seed set, mature plant height and grain yield per panicle is presented in Appendix 8. The earliest hybrids were CK60A × IESV 23010DL and MA6 × S35. The commercially released varieties *Tegemeo* and *Wagita* took the longest time (72 days) to flowering The check variety *Macia* took longer time (67.3 days) to attain 50% flowering as compared to CK60A × IESV 23010DL and MA6 × S35. Overall, 39 hybrids (42%) were early maturing as they attained flowering within a range of 56 – 65 days, while 54 hybrids (58%) were medium maturing, taking between 66 and 75 days.

The best hybrid for seed setting was SDSA1×IESV 91104DL (99.3%) whereas ICSA479 × Siaya66-2 was the poorest at 39.3% seed set. Eighty nine (89) hybrids expressed seed set above three quarter of the head (80 to ≤ 100%) whereas only 3 hybrids expressed seed set just above the two thirds of the panicle (60 to ≤ 80%.

The performance of the best ten hybrids compared to local check is given in Table 7 but detailed information is presented in Appendix 8. Three (3) among the best 10 hybrids resulted from restorer line KARI MTAMA 1, and 4 of the high yielding hybrids resulted from restorer line IESV91104DL. Hybrid ICSA 88001 X KARI MTAMA 1 was the best yielder across locations with an average of 6.3 t/ha. The check variety produced 2.7 t/ha. The hybrids ATX623×KARI MTAMA 1 and ATX623 × IESV91104DL were relatively similar in all attributes assessed.

Table 7: Morphological properties of the top 10 hybrids selected across Kiboko, Miwaleni and Ukiriguru during 2011-2012 season

	Entry	DAF	TL	%SS	HT	PS	Y (t/ha)
1	ICSA 88001 X KARI MTAMA 1	66	1	97.1	227.7	5	6.3
2	ICSA 6 X ICSR 162	67	1	96.4	207.7	6	6.2
3	ATX 623 X IESV 91104 DL	66	1	93.7	213.9	6	6.2
4	ATX 623 X KARI MTAMA 1	65	1	97.1	209.2	6	6.1
5	ICSA 88006 X KARI MTAMA 1	68	1	97.6	223.9	6	5.2
6	ICSA 44 X IESV 91104 DL	67	1	98.5	221	6	4.9
7	ICSA 12 X IESV 91104 DL	68	1	98.2	235.3	6	4.0
8	SDSA 1 X ICSR 93001	68	1	98.2	212.8	6	3.9
9	ICSA 15 X IESV 91104 DL	68	1	98.4	230.5	6	3.9
10	ICSA 88001 X ICSR 93034	65	2	85	241.3	5	3.9
11	Macia (check)	67	1	96.5	117.9	7	2.7

Note: DAF = Days to 50% flowering; HT= Plant height (cm); TL= Number of tillers; %SS = percent seed setting; PS= Panicle shape; Y = Grain yield (t/ha). Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

Results from individual locations (Appendices 9, 10 and 11). Hybrids ICSA88001×ICSR93034 and ATX623×IESV 91104 DL out-yielded others at Kiboko; ICSA15×IESV 91104 DL and SDSA1×ICSR93001 at Miwaleni and ICSA88001×KARI MTAMA1; ICSA12×IESV91104DL at Ukiriguru. Figure 6 illustrates some of the selected hybrids at Kiboko, Miwaleni and Ukiruguru.

ATX623×KARI MTAMA1 ICSA15×IESV 91104DL ICSA12×IESV 91104DL

Figure 6: Some of the high yielding sorghum hybrids across test locations

(Source: Author, 2015)

The best ten hybrids at Ukiriguru are presented in table 8 and Appendix 9. The first two hybrids were developed using the same restorer line KARI MTAMA 1. The check variety yielded about 50% lower than the best hybrid at Ukiriguru. The best hybrid ICSA 88006 × KARI MTAMA 1 yielded 6.9 t/ha while the lowest yielder was IESA 2 × ICSR 24007 that produced an average of 1.8 t/ha. The overall yield at Ukiriguru was 3.1 t/ha. Hybrids at Ukiriguru took 70 days to attain 50% flowering and percent seed set averaged 93.4%. The plant height was relatively lower (154.4cm) as compared to other locations.

The best hybrid took 4 more days to attain 50% flowering compared to check and 5 more days compared to overall mean. Majority of hybrids at Ukiriguru yielded higher than other locations.

Table 8: Yield performance of the top 10 hybrids and check variety selected at Ukiriguru during 2011-2012 growing seasons

	Entry	DAF	TL	%SS	HT	PS	Y (t/ha)
1	ICSA 88006 × KARI MTAMA 1	75.0	0.0	96.5	173.3	4.0	6.9
2	ICSA 88001 × KARI MTAMA 1	65.0	0.0	96.7	189.9	3.0	6.2
3	ICSA 12 × IESV 91104 DL	73.0	0.0	98.2	183.5	4.0	6.0
4	ICSA 88001 × ICSR 93034	66.0	1.0	83.0	195.5	3.0	6.0
5	ICSA 366 × *Macia*	64.0	1.0	93.2	137.0	4.0	4.4
6	ICSA 90001 × ICSR 24008	73.0	0.0	90.7	150.2	3.0	4.2
7	ICSA 12 × ICSR 162	67.0	0.0	97.5	174.8	3.0	4.2
8	ICSA 6 × ICSR 162	70.0	0.0	94.9	180.3	4.0	4.2
9	ICSA 90001 × ICSR 172	71.0	0.0	96.9	133.0	3.0	4.0
10	ICSA 15 × ICSR 162	69.0	0.0	91.9	183.9	4.0	4.0
11	*Macia* (check)	71.0	0.0	97.9	125.7	6.0	2.9

Note: DAF = Days to 50% flowering; HT= Plant height (cm); TL= Number of tillers; %SS = percent seed setting; PS= Panicle shape; Y = Grain yield (t/ha). Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

The best ten hybrids selected at Kiboko for yield performance are presented in Table 9 whereas detailed overall performance is given in appendix 10. In comparison for grain yield, all selected hybrids were superior to the check variety. The best hybrid at this location was ICSA 88001 × ICSR 93034 (6.7 t/ha) while the check variety, *Macia* produced 2.9 t/ha. The lowest yielder at Kiboko was MA 6 X MAKUENI LOCAL which yielded 2.6t/ha whereas overall average yield at this location was 4.2 t/ha.

The hybrids made up of KARI MTAMA 1 and IESV 91104 DL as pollen donor featured among the best 10 hybrids at Kiboko location. In terms of seed set ability and days to 50% flowering, evaluated hybrids expressed 99.8% and 72 days, respectively. Additionally, the evaluated hybrids at Kiboko grew taller (221.8 cm) taller than other locations.

Table 9: The best 10 hybrids and check variety selected basing on yield performance at Kiboko in 2011-2012 season

No	Genotype	DAF	TL	SS (%)	HT(cm)	PS	Y(t/ha)
1	ICSA 88001 × ICSR 93034	66	0	89.3	267.7	5	6.7
2	ATX 623 × IESV 91104 DL	66	0	99.8	248.8	8	6.6
3	ICSA 88001 × KARI MTAMA 1	66	0	98.3	251.9	6	6.2
4	ICSA 276 × IESV 91104 DL	67	0	97.5	220.6	6	6.1
5	ATX 623 × KARI MTAMA 1	64	0	98.0	237.9	7	5.9
6	ICSA 6 × ICSR 93034	68	0	95.3	232.8	7	5.7
7	ICSA 90001 × ICSR 24008	71	0	98.7	188.1	6	5.6
8	ICSA 12 × IESV 91104 DL	67	0	99.4	258.6	6	5.5
9	ICSA 293 × ICSR 24009	68	0	99.2	196.3	6	5.5
10	ICSA 6 × ICSR 162	66	0	98.8	212.0	8	5.4
11	*Macia* (check)	68	0	93.1	120.1	7.7	3.6

Note: DAF = Days to 50% flowering; HT= Plant height (cm); TL= Number of tillers; %SS = percent seed setting; PS= Panicle shape; Y = Grain yield (t/ha). Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

The ten highest yielding sorghum hybrids at Miwaleni are presented in table 10, but the detailed information for all hybrids is provided in Appendix 11. Majority of hybrids resulted from parental lines (restorers) IESV 91104 DL and KARI MTAMA 1 were very high yielding. All the best ten hybrids at Miwaleni did not produce tillers. The best hybrid in terms of yield was ICSA 15 × IESV 91104 DL (6.1 t/ha) and the least was SDSA 4 X ICSR 24009 (1.3t/ha).

The overall mean for yield was 3.0t/ha whereas the check variety produced 2.1 t/ha. Days to flowering and percent seed set averaged 63 and 94.6, respectively. The average height for hybrids at Miwaleni was 209 m tall. Apart from the hybrid ATX 623 × ICSR 23019 that produced brown seed grains, the other 9 top hybrids produced white grains.

Table 10: The phenotypic attributes and grain yield of the 10 highest yielding sorghum hybrids and check variety at Miwaleni in 2011-2012 season

	Entry	DAF	TL	SS (%)	HT(cm)	PS	Y (t/ha)
1	ICSA 15 × IESV 91104 DL	62	0.0	98.7	269.6	6	6.1
2	SDSA 1 × ICSR 93001	67	0.0	98.8	231.9	6	5.7
3	ICSA 6 × ICSR 162	67	0.0	96.4	232.4	6	5.5
4	ATX 623 × ICSR 23019	64	0.0	89.5	220.0	8	5.5
5	ATX 623 × KARI MTAMA 1	61	0.0	95.8	228.5	6	5.4
6	ICSA 44 × IESV 91104 DL	62	0.0	99.4	243.3	7	5.3
7	ATX 623 × IESV 91104 DL	62	0.0	98.1	257.9	7	5.1
8	ICSA 90001 × ICSR 92003	65	0.0	99.6	183.5	6	5.1
9	ICSA 90001 × ICSR 89001	68	0.0	99.0	148.4	6	4.9
10	ICSA 88001 × KARI MTAMA 1	65	0.0	97.6	244.7	6	4.6
11	*Macia* (check)	63	0.0	99.2	132.1	6	2.7

Note: DAF = Days to 50% flowering; HT= Plant height (cm); TL= Number of tillers; %SS = percent seed setting; PS= Panicle shape; Y = Grain yield (t/ha). Classification for DAF: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

4.3.2 Correlation between yield traits in sorghum

Results for correlation coefficients in hybrids and parental lines is presented in Table 11. Although the values were relatively low, there was significant ($p \leq 0.05$) and positive correlation between grain yield and days to 50% flowering, seed set percent, productive tillers and panicle length. The plant height was negatively correlated to days to 50% flowering.

Panicle exertion was significant but negatively correlated to plant height. Moreover, panicle exertion was not correlated to days to 50% flowering, percent seed set and productive tillers. Results indicated that panicle width was not correlated to any of the traits tested in sorghum.

Table 11: Correlation coefficients among grain yield and its components for sorghum hybrids and parents evaluated at Kiboko, Miwaleni and Ukiriguru locations

Trait	Grain yield (t/ha)	Days to flower	Seed set (%)	Plant height (cm)	Productive tillers	Panicle exertion (cm)	Panicle length (cm)	Panicle width (cm)
Grain yield (t/ha)								
Days to 50% flowering	0.10*							
Seed set (%)	0.24*	0.30						
Plant height	0.40*	- 0.33*	0.01					
Productive tillers	0.31*	0.22	0.03	0.04				
Panicle exertion	0.14	0.00	0.00	0.01	0.00			
Panicle length (cm)	0.09*	0.15	0.07	0.11	0.20	0.21		
Panicle width (cm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Note: * = significant at $p< 0.05$; N = 121

4.3.3 Genotype and genotype-by-environment (GGE) interaction and stability in sorghum

Results revealed significant ($p \leq 0.05$) effects of environment (ENV), genotype (GEN) and genotype-by-environment (GEN × ENV) interaction for sorghum hybrids and their parental lines evaluated at Kiboko, Miwaleni and Ukiriguru locations as presented in table 12 and table 13, respectively. There were very high mean squares values recorded for environments and genotypes for both hybrids and parental lines.

Table 12. Analysis of variance for some sorghum parents for yield and yield traits evaluated at Kiboko, Miwaleni and Ukiriguru in 2011/12 season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environments (ENV)	2	2054060	1027030	2.13	<.001
Genotypes (GEN)	73	57943166	793742	1.64	<.001
GEN × ENV	146	149148212	684166	1.42	<.001
Residual	990	478332709	483164		
Total	1211	716052860			

Table 13. Analysis of variance for sorghum hybrids evaluated for yield and yield traits at Kiboko, Miwaleni and Ukiriguru in 2011/12 season

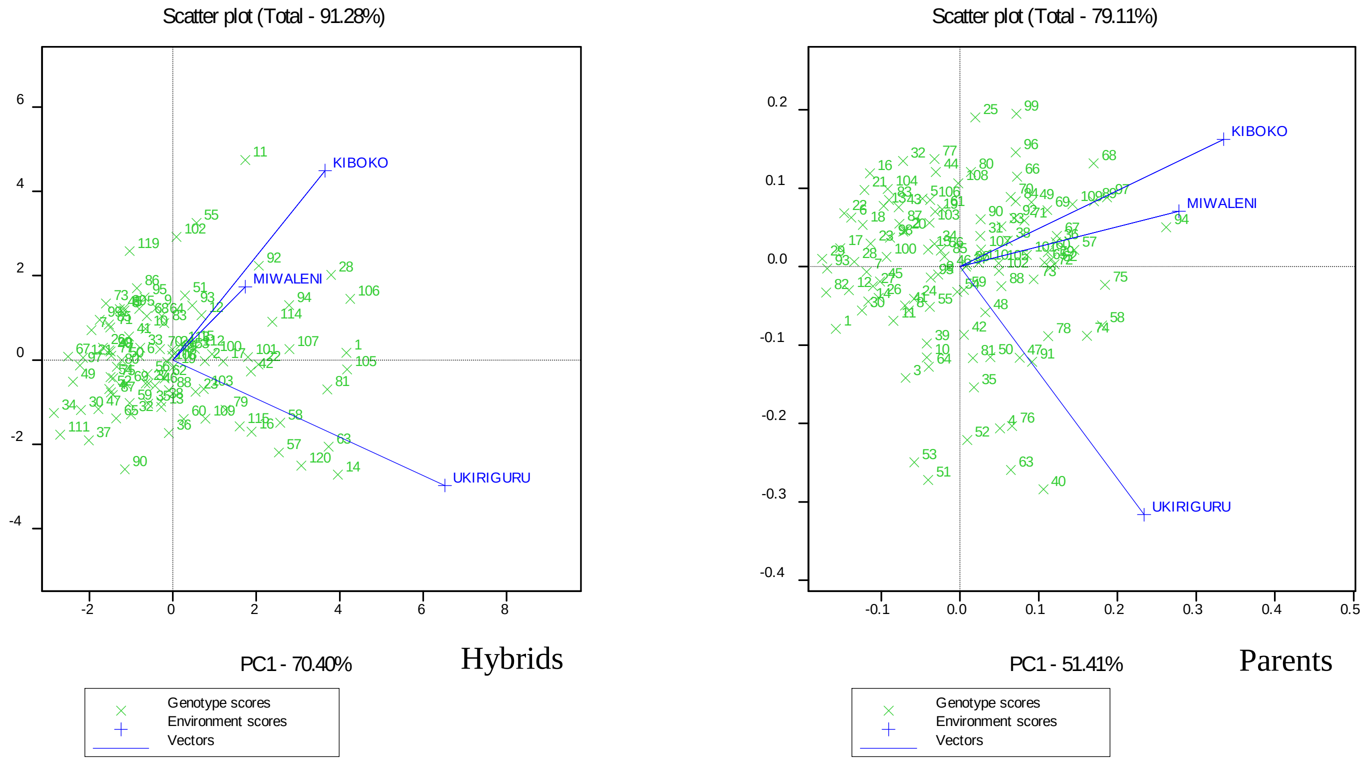
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr**.
Environment (ENV)	2	265220.9	132610.5	210.85	<.001
Genotypes (GEN)	92	208499.6	2266.3	3.6	<.001
GEN × ENV	184	141514.4	769.1	1.22	<.001
Residual	588	369815.6	628.9		
Total	866	1004082.1	1139.7		

4.3.3.1 Ranking environments basing on their performance

Results from the GGE biplot across test environments for both hybrids and their parents is demonstrated on Figure 7. The length of environmental vectors connecting Kiboko and Ukiriguru from the origin is longer than that of Miwaleni.

Moreover, the biplot results revealed that Kiboko and Miwaleni were at an acute angle between them from the origin of the biplot whereas Kiboko and Ukiriguru were at an obtuse angle to each other for both hybrids and parental lines evaluated

The first two principal components (PCA1 and PCA2) were used to generate 2-dimensional GGE biplots and the components explained 70.4% and 20.88% effects respectively in hybrids whereas in parental lines was 51.41% and 27.7% respectively (Figure 7).

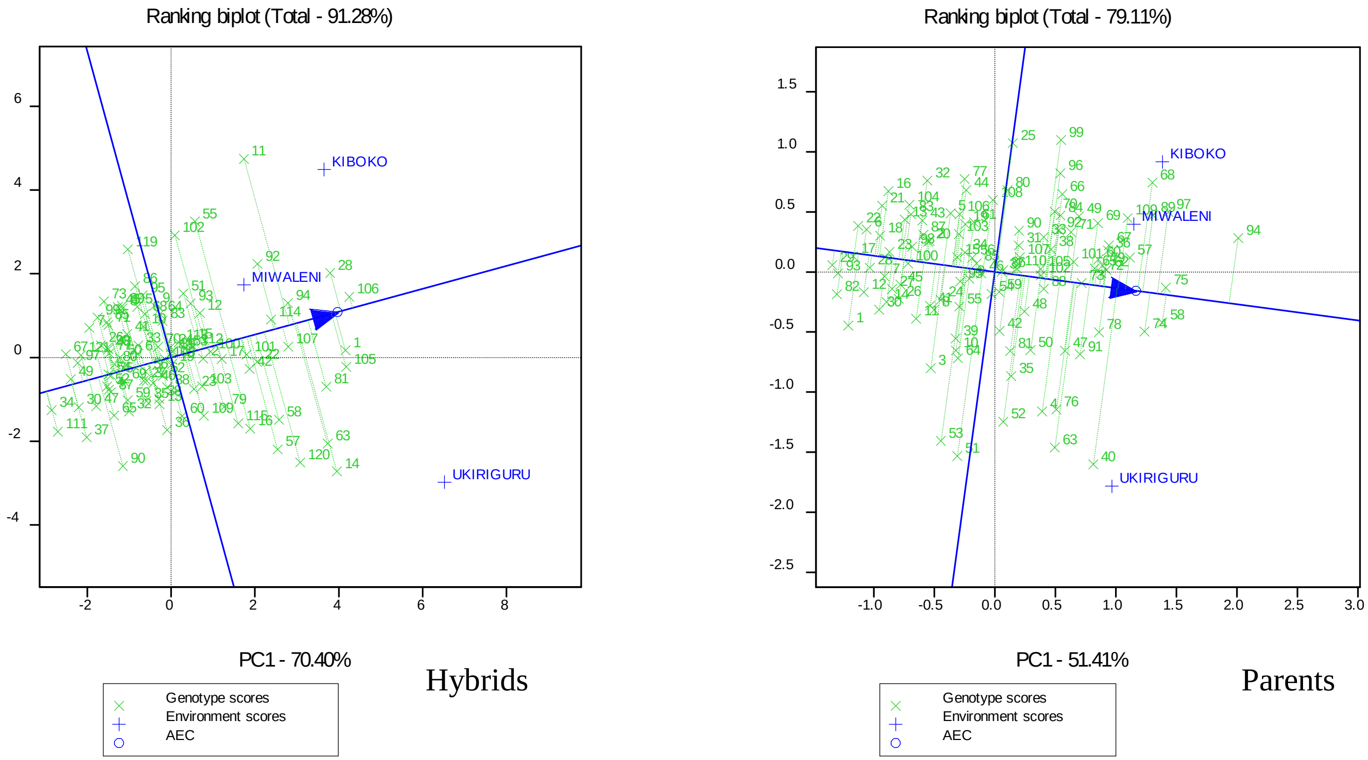


Figures 7: Correlation among test environments for hybrids and parents

4.3.3.2 Ranking hybrid and parents basing on yield and stability

The ranking biplot of hybrids and their parents on the basis of yield and stability is shown in Figure 8. Results show that the stable genotypes, those with smallest perpendicular line and close to Average Environmental Coordinate (AEC) were ATX623×IESV 91104DL (entry 106) among hybrids and IESV 91131DL (entry 75) for R-lines.

On contrary, unstable genotypes, those with longest perpendicular line and close to AEC were ICSA44×IESV91104DL (entry 81) hybrid and IESV23010DL (entry 68) R-line. The restorer line IESV23010DL was also among the high yielders but less stable.



Hybrids

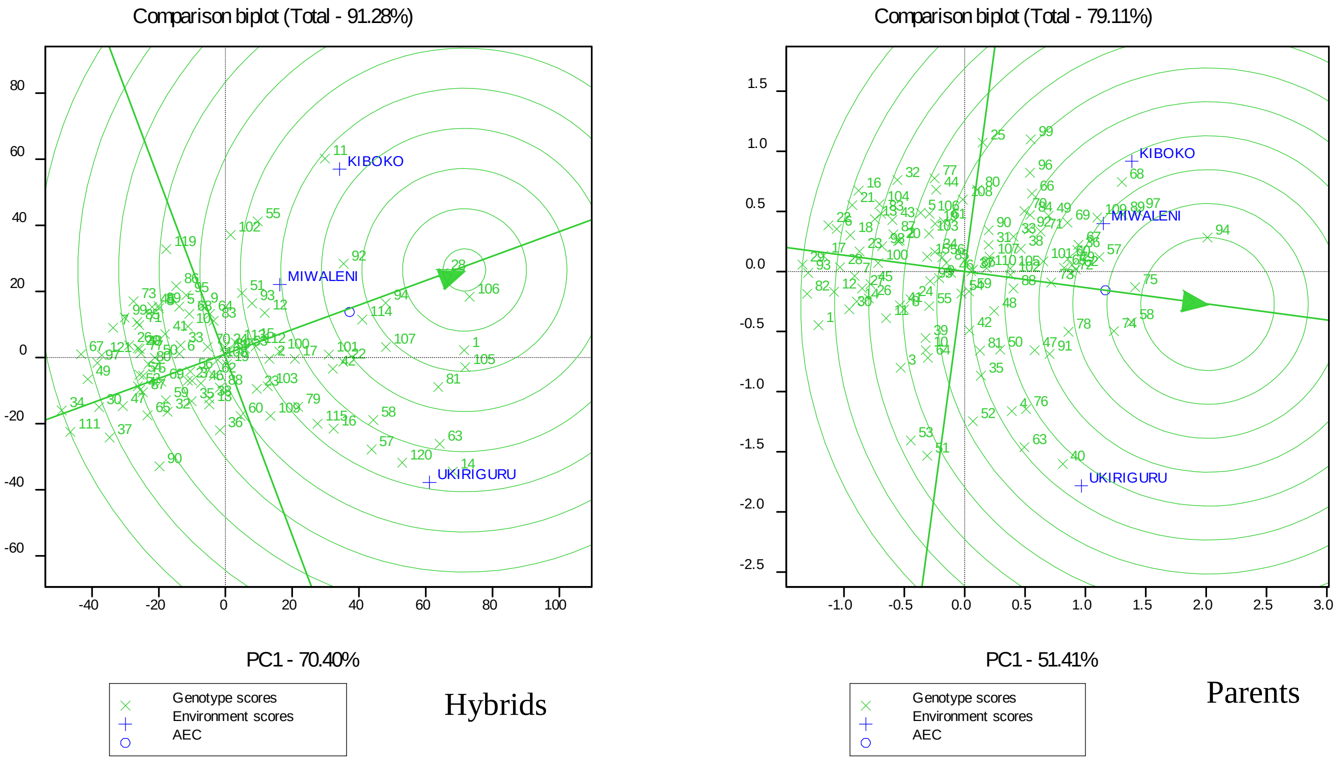
Parents

Figure 8: The GGE biplots based on yield performance and stability of hybrids and parents

4.3.3.3 GGE biplot for comparison of hybrids and parents with the ideal genotype

The GGE biplots analysis revealed that the ideal hybrid that was at the centre of the concentric circles was ICSA88001 × KARI MTAMA 1(entry 28) as indicated in figure 9. Same hybrid had high and stable. The hybrids that yielded high close to ideal hybrid were ATX623 KARI MTAMA 1 (entry1), ICSA12 × IESV91104DL (entry 94), ICSA6 × ICSR162 (entry 105) and ATX623 × IESV91104DL (entry 106).

The GGE biplots for the parents showed that IESV91104DL (entry 94) was the best parent across environments. Other good parents that yielded high and close to the best parent were IESV93034 (entry 58), IESV 23014DL (entry 74) and IESV91131DL (entry 75).



Hybrids

Parents

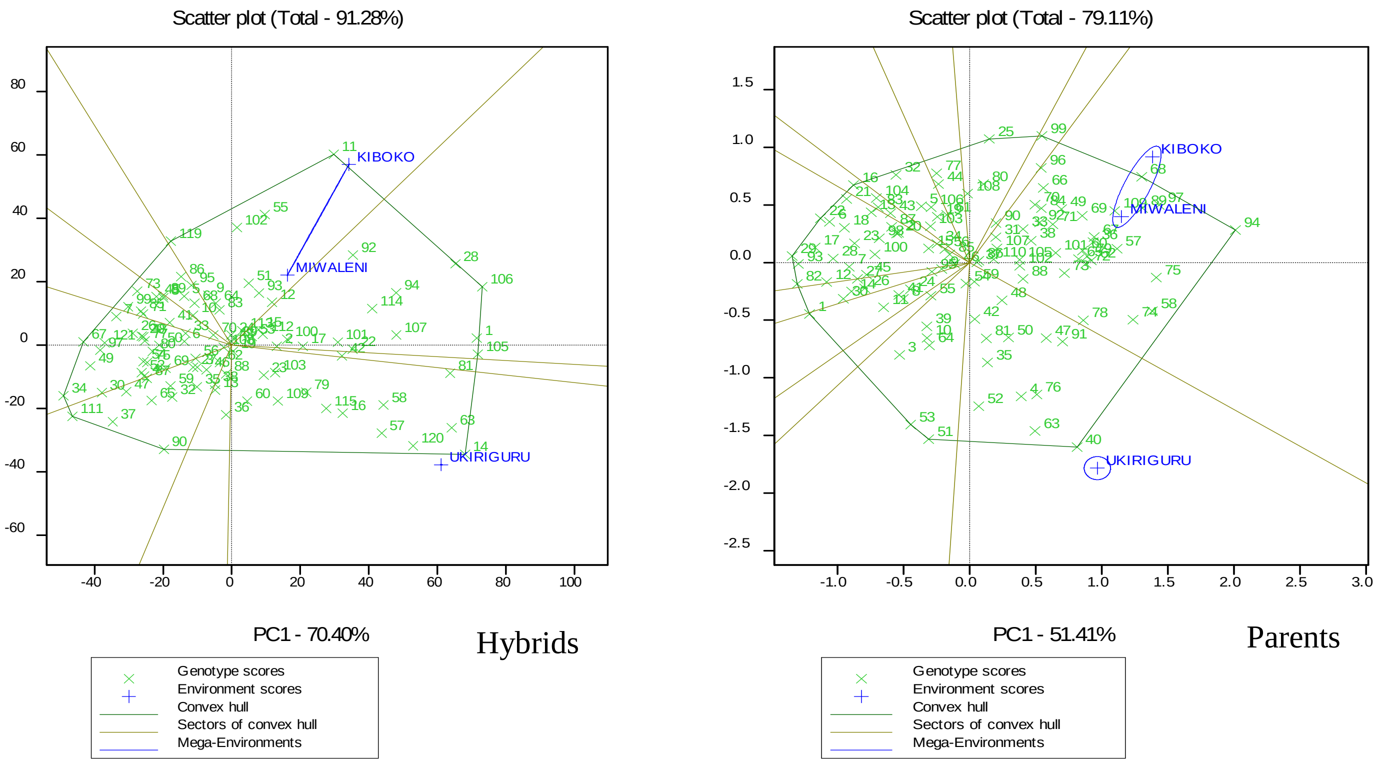
Figure 9 . The GGE biplots for comparison of the sorghum hybrids with the ideal genotype

4.3.3.4 Ranking genotypes basing on their best suitable environment (which-won-where)

The polygon view of *which-won-where* for hybrids and parents is presented in Figure 10. Perpendicular lines divides the polygon into sectors. The highest performing genotypes (hybrids and parents) are located at the vertex of the polygon. Results for hybrids revealed 9 sectors and a mega environment comprised of Kiboko and Miwaleni.

Hybrids ATX623×IESV91104DL (entry 106) and ICSA88001× KARI MTAMA 1 (entry 28) were the highest yielders in all three locations. Results further revealed that the highest yielder at mega environment (Kiboko and Miwaleni) was ICSA88001×ICSR93034 (entry 11), whereas the highest yielder at Ukiriguru was ICSA15 × IESV91104DL (entry 14).

The polygon view for the parents revealed 12 sectors. The results also revealed one mega environment formed by Kiboko and Miwaleni. Restorer line IESV94104DL (Entry 94) was the highest yielder in all the environments, whereas the best yielder at mega environment was IESV 23010DL (entry 68), whereas KARI MTAMA 1 (entry 40) was the best yielder at Ukiriguru. These genotypes produced bold grain on long and semi compact panicles (Figure 11).



Hybrids

Parents

Figure 10. Which genotype won where and mega-environments with GGE biplots for hybrids

IESV 23010 DL IESV 91104 DL

Figure 11. Panicle form of some promising sorghum lines evaluated in 2011/12

(Source: Author, 2015)

4.4 Heritability, expected genetic gain and heterosis for the various hybrids

4.4.1 Heritability and expected genetic gain

Estimation of genetic parameters for the sorghum lines is presented in Table 12. Percentage phenotypic coefficient of variation (PCV%) was higher in all traits evaluated in sorghum. The highest GCV was expressed in panicle exertion while the lowest was expressed in days to 50% flowering. The highest PCV and GCV values were observed for panicle exertion (55.8 and 49.2 %), followed by plant colour (30.6 and 29.4 %), plant height (24.4 and 23.9 %), panicle length (19.4 and 18.9 %), grain yield per plant (12.9 and 11.2 %) and the least was days to 50% flowering (5.2 and 4.3 %).

Broad sense heritability ranged from 6 to 96% for all the traits. The most heritable traits were plant height (96%) and panicle length (95%). Mid rib colour and grain colour expressed very low heritability and selection response, respectively. Highest genetic gain and consequently best selection response was expressed in plant height. The expected genetic gain as percentage of genotype means was highest in panicle (89.4%) and lowest in grain colour (4.8%). In addition, high heritability together with low expected genetic gain was expressed in number of days to 50% flowering and panicle shape.

Table 14: Estimate of genetic parameters in sorghum parents evaluated at Kiboko, Miwaleni and Ukiriguru during 2011-2012 season

Traits	**Mean**	**SED**	**δ^2g**	**δ^2p**	**GCV**	**PCV**	**h^2** (%)	**GG**	**EG**	**R%**
Grain yield per plant (g)	123.5	10.9	189.6	256.2	11.2	12.9	74	24.4	19.7	86.0
Days to 50% flowering	69.2	1.2	8.95	12.71	4.3	5.2	70	5.2	7.5	83.9
Midrib color	1.5	0.2	0.05	0.72	14.2	56.2	06	0.1	7.4	25.3
Plant height (cm)	162.4	8.2	1508	1575	23.9	24.4	96	78.3	48.2	97.8
Plant color	1.4	0.1	0.17	0.18	29.4	30.6	92	0.8	58.3	96.2
Tillers per plant	0.6	0.2	0.03	0.13	28.2	63.1	20	0.2	26.0	44.7
Panicle shape	6.2	0.4	0.48	0.81	11.1	14.4	60	1.1	17.7	77.3
Panicle (cm)	6.7	1.7	10.9	14.09	49.2	55.8	78	6.0	89.4	88.2
Panicle length (cm)	25.3	1.3	23.03	24.28	18.9	19.4	95	9.6	38.0	97.4
Panicle width (cm)	7.1	0.6	0.93	1.33	13.7	16.3	70	1.6	23.5	83.7
Awns at maturity	0.5	0.01	0.01	0.04	19.6	39.2	25	0.1	20.2	50.0
Grain color	2.3	0.3	0.04	0.48	8.5	30.5	08	0.1	4.8	27.7

Note: GCV = genotypic coefficient of variation; PCV = phenotypic coefficient of variation; h^2 = broad sense heritability; δ^2g = genotypic variance; δ^2p = phenotypic variance; GG=Genetic gain; EG = expected genetic gain as percent mean; R = selection response

4.4.2 Heterosis and heterobeltiosis of the sorghum hybrids

Results for average heterosis and heterobeltiosis for the best eight sorghum hybrids is given in Table 13 but detailed information is given in Appendix 12. These 8 hybrids possessed positive average heterosis and heterobeltiosis for yield. Negative (desirable) average heterosis for days to flowering, varied from -4.5 to -17.53%, whereas heterobeltiosis ranged from -5.23 to -14%. The most negative average heterosis and heterobeltiosis was expressed in the cross ICSA88001×*Macia*. Only one hybrid ATX623 × KARI MTAMA1 expressed desired average heterosis and heterobeltiosis for days to 50% flowering, plant height and yield. However, all eight best hybrids had negative average heterosis and heterobeltiosis for days to flowering. It was interesting to note that three out of identified 8 best hybrids were made from KARI MTAMA 1.

Table 15: Average heterosis and heterobeltiosis for the best sorghum hybrids at Kiboko, Miwaleni and Ukiriguru

		Days to 50% flowering		Plant height (cm)		Grain yield /panicle (g)	
No	Cross	**H_{MP}**	**H_{BP}**	**H_{MP}**	**H_{BP}**	**H_{MP}**	**H_{BP}**
1	ATX623xIESV91104DL	-5.4**	-6.43*	32.6**	11.8*	76.1**	38.5*
2	ATX623xKARI-MTAMA1	-7.3**	-5.6*	-37.2**	-23.2**	80.5**	60.1**
3	ICSA11xS35	-4.3*	-7.9**	52.9**	34.7**	81.9**	77.2*
4	ICSA15xTEGEMEO	-10.1**	-7.5**	74.4**	-53.6**	68.2**	57.6*
5	ICSA293xICSR24009	-9.5**	-6.3*	8.9	8.7	79.1**	54.5*
6	ICSA88001xKARI-MTAMA1	-8.1**	-9.4**	41.9**	34.2**	72.7**	51.4*
7	ICSA88006xKARI-MTAMA1	-5.4**	-4.2	56.8**	30.7**	77.2**	58.9*
8	SDSA1xICSR93001	-9.3**	-3.1	50.5**	41.2**	78.1**	49.2*

Note * and ** significant at 1% and 5%, respectively ; H_{MP} = Mid parent heterosis (average heterosis) and H_{BP} = Better parent heterosis (heterobeltiosis)

A total of 45 and 27 hybrids expressed negative and significant ($p \leq 0.05$) in days to flowering for average heterosis and heterobeltiosis respectively. Average heterosis for plant height varied from -17.2% to -55.67%; whereas heterobeltiosis varied between -11.44 to -53.61%. The hybrids ICSA15×TEGEMEO and ATX623×KARI-MTAMA1 expressed high heterobeltiosis for plant height. Productive tillers ranged from 23.08 to

75.76% and 25.77 to 56.52% for average heterosis and heterobeltiosis respectively. Significant positive heterosis and heterobeltiosis for productive tillers were expressed in the cross ICSA687×IESV23011DL.

There were significant differences in panicle length and width for both average heterosis and heterobeltiosis. Heterobeltiosis for panicle length ranged from 10.57 to 17.08%, whereas that of panicle width ranged from 20.99 to 41.36%. Expression of both average heterosis and heterobeltiosis for panicle ranged from 11.64 to 91.10% and 19.38 to 86.86% respectively. The hybrids that had positive and significant values for panicle were 39 and 26 for average heterosis and heterobeltiosis respectively. The highest heterobeltiosis for grain yield was 77.18% (ICSA11×S35). The same hybrid had high average heterosis (81.90%). The lowest heterobeltiosis and average heterosis for grain yield was 18.3% and 31.4% respectively.

Heterobeltiosis for yield and some yield components from individual location is presented in Appendix 13. None of the hybrids expressed significant useful heterobeltiosis for all the traits at all the three locations. However, the hybrids CK60A×R8602 and ICSA687×ICSR162 exhibited significant desirable heterobeltiosis for both days to 50% flowering and panicle length.

The lowest heterobeltiosis (-22.82) for days to 50% flowering was expressed in the cross ICSA11×SP74279 at Ukiriguru. The lowest heterobeltiosis for mature plant height was -50.59% recorded at Kiboko in ICSA12×KARI MTAMA1. The highest heterobeltiosis (46.33%) was expressed in panicle length by the cross ICSA90001× ICSR24008.

Table 14 present hybrid that are suited to specific locations for specific traits. The A -line ATX623 produced medium height, high yielding hybrids, whereas ICSA11 produced short statured plants that took shorter time to attain 50% flowering. Basing on heterobeltiosis for grain yield trait, ICSA15×TEGEMEO and ICSA89003×ICSR89058 were best suited for Kiboko; ATX623×ICSR23019 and ATX623×IESV91104DL for Miwaleni; ICSA366×MACIA and ICSA88006×KARI MTAMA 1 for Ukiriguru.

Best hybrids that expressed desired heterobeltiosis for days to 50% flowering hence early maturity include IESA2×ICSR24007 and MA6×MAKUENI LOCAL for Kiboko; ICSA366×MACIA and IESA2×ICSR24010 for Miwaleni; ICSA11×SP74279 and ICSA88001×MACIA for Ukiriguru

Table 16: Sorghum hybrids that exhibited high heterobeltiosis for selected attributes at Kiboko, Miwaleni and Ukiriguru

TRAIT	**KIBOKO**	**MIWALENI**	**UKIRIGURU**
Days to 50% flowering	IESA2×ICSR24007 MA6×MAKUENI LOCAL	ICSA366×*MACIA* IESA2×ICSR24010	ICSA11×SP74279 ICSA88001×*MACIA*
Plant height (cm)	ATX623×KARI MTAMA1 ICSA12×KARI MTAMA1	ICSA276×IESV91104DL ICSA6×ICSR93034	ICSA11×S35 ICSA6×ICSR93034
Panicle length (cm)	ICSA44×MAKUENI LOCAL ICSA88001×ICSR108	ICSA12×IESV91104DL ICSA687×ICSR172	CK60A×R8602 ICSA44×MAKUENI LOCAL
Grain yield (t/ha)	ICSA15×TEGEMEO ICSA89003×ICSR89058	ATX623×ICSR23019 ATX623×IESV91104DL	ICSA366×*MACIA* ICSA88006×KARI MTAMA1

4.5 General and specific combining abilities of the hybrid sorghum parents

The effect of environments, hybrid and male parents were significant ($P \leq 0.05$) for days to flowering, productive tillers, plant height, panicle length, panicle width and yield per panicle (Table 15). The effect of female parents was not significant for days to 50% flowering and the number of productive tillers.

The interaction between female and male parents was not significantly different across environments for days to 50% flowering, plant height and panicle . The Environment × Female × Male interactions were significant for productive tillers and plant height.

Table 17: Mean squares of combining ability in some traits evaluated in sorghum at Kiboko, Miwaleni and Ukriguru during 2011/2012 growing seasons

		Mean squares					
Source of Variation	**Df**	**Days to 50% flowering**	**Productive tillers**	**Plant height (cm)**	**Panicle length (cm)**	**Panicle width (cm)**	**Grain yield/ panicle (g)**
Environment (Env)	2	2382.2*	468.8*	179447.7*	2839.2*	962.6*	111459.7*
Hybrid	92	56.5*	3.2*	5316.3*	49.5*	9.6**	1700.6*
Females	27	157.0	5.7	6714.1*	106.1*	18.4*	1933.9*
Males	45	18.7*	2.0*	7540.4*	35.2*	6.9*	1587.2*
Females × Males	26	8.9	2.5**	528.6	12.4**	4.4*	1628.6*
Env × Hybrid	184	13.4*	2.9	616.1*	8.2*	3.4	785.2
Env × Females	54	19.2*	4.8*	720.3*	10.7*	5.3	883.4
Env × Males	78	11.1	1.9	550.6*	8.8*	2.9	721.6
Env × Females × Males	52	10.8	2.4*	606.2*	4.8	2.1	778.5
Error	420	5.6	0.9	221.9	4.7	1.5	580.6

Note: *, **= significant at 1% and 5%, respectively

The GCA for the best 10 parents is presented in Table 16 and the GCA for all parents is presented on Appendix 14. There was no parent that exhibited good combining ability for all traits. The top 3 male sterile and restorer lines for early flowering were MA6, CK60A, ICSA11, and IESV 23010DL, S35, SP74279.

The significant negative GCA was recorded for plant height in 14 A- lines and 19 R-lines. Only 9 A-lines showed significant positive GCA effect for productive tillers. The top three general combiners for this trait were ICSA654, ICSA687, and ICSA 479 with GCA effect of 2.44, 1.88 and 1.83, respectively. Significant positive GCA effect on panicle width was recorded for 11 A- lines and 20 R-lines. The A-lines ICSA687, ICSA88001 and ICSA293 were the top combiners for panicle width.

Only 4 A-lines *viz* ICSA9, ICSA654, ICSA11 and ICSA371 expressed significant negative GCA for panicle width. Twelve male sterile lines had positive GCA in all the 3 locations for panicle length of which only four lines; SDSB4, ICSB90001, ICSB88001 and ICSB89004 were the best for this trait. ICSR89059, ICSR43 and ICSR89001 were the highest general combiners for the panicle length among the male parents.

Table 18: General combining ability of the best ten sorghum parents for selected traits at Kiboko, Miwaleni and Ukiriguru, 2011/12

S/No	Genotype	Days to 50% flowering	Productive Tillers	Height (cm)	Panicle (cm)	Panicle length (cm)	Panicle width	Grain colour	Grain yield (g)
1	BTX623	-1.63*	-0.01	1.94*	-0.17	-0.39*	-0.24*	-0.02	104.35*
2	CK 60B	-5.43*	0.56*	-15.42*	3.72*	-2.48*	-0.59*	0.46**	109.65*
3	ICSB 11	-4.52*	0.25*	-14.72*	1.43*	-1.75*	-1.40*	0.09*	82.10*
4	ICSB 15	-0.03	0.1	13.98*	-0.16	1.27*	-0.34*	-0.22*	379.47*
5	ICSR 23019	-0.13	-0.52*	32.27*	-0.78*	0.92**	0.43*	0.31*	326.92*
6	IESV 23010 DL	-6.47*	-0.22*	7.88*	4.69*	-3.08*	-0.58*	0.65*	123.05*
7	IESV 91104 DL	1.14*	-0.02	8.11*	-1.34*	-2.66*	0.57*	-0.35*	364.48*
8	KARI MTAMA 1	-0.66*	-0.1	22.55*	-1.12*	-1.43*	0.52*	-0.30*	107.87*
9	S35	-6.47*	0.93*	23.97*	6.38*	-3.66*	-0.93*	-0.35*	438.43*
10	TEGEMEO	-2.47*	0.41*	43.20*	2.62*	-0.73*	0.36*	-0.19*	743.06*
	MACIA (Check)	-3.15*	0.01	-17.39*	-0.53	-0.11	-0.33*	0.28*	-65.71

Note: * , ** = significant at 1% and 5%, respectively

The positive and highest GCA effects for grain yield was expressed in ICSB293, ICSB6, ICSB15 and BTX623 for female lines and ICSR23019, Tegemeo, IESV91104DL and KARI MTAMA1 for restorers. Based on the location effect (Appendix 15), the GCA on days to 50% flowering (DAF) ranged from -1.0 (Kiboko) to -7.8 (Ukiriguru) for A-lines and -1.1 (Kiboko) to -10.2 (Ukiriguru) for R-lines. Only 10 A- and 17 R- lines had significant negative effect on DAF. The GCA for plant height ranged from -3.4 (Ukiriguru) to -54.5 (Miwaleni) for A-lines and -3.7 (Ukiriguru) to -60.9 (Miwaleni) for R-lines.

Based on yield per plot, the positive significant GCA at Kiboko ranged from 30.37 (ICSR160) to 241.61(ICSR93034) whereas at Miwaleni the range was 78.2 (ISB89004) to 382.8 (IESV92156DL). The minimum and maximum significant GCA effects for the same trait at Ukiriguru was 21.82 (ICSR24010) and 347.82 (IESV23019DL. The R-line, ICSA687 expressed desirable significant GCA effects across all locations for four traits *viz* days to 50% flowering (negative GCA), mature plant height (negative GCA), panicle length (positive GCA) and panicle width (positive GCA).

Six male sterile lines, ICSA366, ICSA371, CK60A, ICSA687, ICSA91002 and ICSA11, and nine R-lines AIHR91075, *Macia*, ICSR38, ICSR24007, IESV91136DL, IESV92172DL, R8602, SP74278 and SP74279 showed desirable significant GCA effects across the 3 locations for days to 50% flowering and plant height. The line ICSA293 revealed negative GCA effects for mature plant height and positive GCA for yield in all the three locations.

The male sterile lines, ICSA88001 and ICSR93003 expressed significant positive (preferred) GCA effects on panicle length and width in the three locations; whereas ICSB6 and IESV91104DL had significant positive effect for panicle width and grain yield. Restorer lines ICSR89001, ICSR89058, IESV91136DL, IESV95022 exhibited significant GCA effect on plant height and panicle length in both agroecologies. The lines ICSB12, ICSB15, ICSR23019 and KARI MTAMA1 expressed positive significant GCA effect for grain yield across environments.

KARI MTAMA1, IESV91104DL, ICSR93034 and A-line ICSB6 had high and positive GCA for grain yield at Kiboko ;whereas ICSR23019, ICSR89001, IESV91104DL, TEGEMEO, ICSB15, ICSB89004 had high GCA for grain yield at Miwaleni. ICSR93001, Gadam, ICSB293 and ICSA88001 out yielded the other lines at Ukiriguru. Only 3 R- lines and 3 restorer lines (Table 17) surpassed all others, and out-yielded the check (*Macia*).

Table 19: General combing ability (GCA) effects for days to 50% flowering, mature plant height and grain yield per plot for best parents

	Parent	DAF		Height (cm)		Grain yield (g)	
		Mean	GCA	Mean	GCA	Mean	GCA
	Female parents						
1.	IESB2	64	-0.33**	110.9	-22.22**	938.0	136.09**
2.	ICSB15	62	-0.03	128.6	13.98**	918.9	379.47**
3.	BTX623	61	-1.63**	172.0	1.94*	898.0	104.35**
	Male parents						
1.	IESV 91104 DL	65	1.14**	166.8	8.11**	1053.5	364.48**
2.	KARI MTAMA 1	63	-0.66**	164.7	2.55**	1027.6	107.87**
3.	IESV91131DL	66	-0.80**	129.3	-20.83**	1013.8	280.53**
	Macia (check)	65	-3.15**	129.6	-7.39**	993.5	95.71

Note: * and ** = significant at 1% and 5%, respectively; GCA = general combining ability; Classification for days to flowering: Very early= <56 days; Early= 56-65 days; Medium= 66-75 days; Late=76-85 days and Very late= >85 days.

The possible combinations for developing hybrids from the best parents basing on the GCA of the parents involved was worked out and ranked (Table 18). A majority of the cross combinations could not possess all traits in a useful manner. Only one combination IESA2×IESV91131DL resulted in a desired direction for all important agronomic traits considered (high and significant negative for days to 50% flowering, high and significant negative for height and high and significant positive yield).

Table 20: Possible hybrids combinations basing on GCA of the best 6 parents

Possible Hybrid combination	**Agronomic trait considered**		
	Days to flowering	*Plant height (cm)*	*Grain yield (t/ha)*
IESA2×IESV91104DL	High×Low	High×Low	High×High
IESA2×KARI MTAMA1	High×High	High×Low	High×High
IESA2×IESV91131DL	High×High	High×High	High×High
IESA2×*Macia*	High×High	High×High	High×Average
ICSA15×IESV91104DL	Average×Low	Low×Low	High×High
ICSA15×KARI MTAMA1	Average×High	Low×Low	High×High
ICSA15×IESV91131DL	Average×High	Low×High	High×High
ICSA15×*Macia*	Average×High	Low×High	High×Average
ATX623×IESV91104DL	High×Low	Low×Low	High×High
ATX623×KARI MTAMA1	High×High	Low×Low	High×High
ATX623×IESV91131DL	High×High	Low×High	High×High
ATX623×*Macia*	High×High	Low×High	High×Average

The SCA estimates of best ten hybrid for seven selected phenotypic traits are presented in Table 19 and detailed information is provided in Appendix 16. The specific combiner for days to flowering with highly significant negative specific combining ability effect were SDSA4×ICSR89059 (-5.26), SDSA4×ICSR43 (-4.59), SDSA1×ICSR43 (-4.06), ICSA479×Siaya#66-2 (-3.87) and ICSA90001×ICSR89001 (-3.44).

Thirteen (13) hybrids had significant positive SCA for number of days to 50% flowering. The hybrid that exhibited high positive specific combining ability for DAF include

MA6×IESV23010DL, CK60A×R8602, CK60A×SP74278 and MA6×S35. Only 5 hybrids; ATX623×IESV91104DL, ICSA12×ICSR172, ICSA15×IESV91104, CK60A×KARI MTAMA1 and ICSA12×KARI MTAMA1, had significant positive SCA for grain yield. Four hybrid had significant negative effect on yield. These poor specific combiners included ICSA276×IESV91104DL, ICSA15×ICSR162, CK60A×IESV23010DL and ICSA11×ICSR172.

Table 21: Specific combining ability of ten top sorghum parents based on yield at Kiboko, Miwaleni and Ukiriguru.

No	Cross	Days to 50% flowering	Tillers	Height (cm)	Panicle (cm)	Panicle length (cm)	Panicle width (cm)	Grain yield (g)
1	ATX623×IESV91104DL	-0.02*	-0.22	-11.08	-0.44	0.13	-0.05	276.99**
2	CK60A×KARI-MTAMA1	-1.95*	0.69	-4.33	-0.42	0.65	1.15*	332.3**
3	ICSA12×ICSR172	-2.27*	-0.55	-7.81	0.73	1.47	0.41	435.19*
4	ICSA15×IESV91104DL	0.42	0.07	-14.62*	0.66	-1.1	-0.66	267.83**
5	ICSA479×SIAYA66-2	-3.87**	-1.83**	0.62	7.08**	8.99**	1.22**	485.54*
6	ICSA90001×ICSR89001	-3.44**	0.25	29.61**	3.70*	-3.32**	-1.16*	129.33
7	IESA2×ICSR24008	-2.67*	-0.13	22.82**	-0.37	0.97	-0.47	392.20*
8	IESA2×ICSR24009	-2.46*	0.08	-5.27	-0.88	-0.37	0.23	229.93
9	SDSA1×ICSR43	-4.06**	0.23	-11.95	6.00**	-1.05	0	172.67
10	SDSA4×ICSR89059	-5.26**	0.81	3.88	2.92*	-4.94**	0.95*	211.34

Note: *, ** significant at 1% and 5%, respectively

The specific combiner that showed significant ($P < 0.05$) and positive effects for productive tillers per plant were ATX623×*Macia*, ICSA88001×ICSR 93034 and ICSA90001×ICSR162. Five hybrids; ICSA654×ICSR153, ICSA89003×IESV23011DL, ICSA479× Siaya#66-2 and ICSA687×ICSR162 showed highly significant negative SCA for tillering. Thirteen (13) hybrids expressed significant negative (desired) SCA for height. The best hybrid for plant height comprised of ICSA376×IESV23O13DL (-43.90), ICSA6×ICSR93034 (-43.25), ICSA276×IESV91104DL (-31.26), MA6×S35 (-28.35) and

MA6×Makueni local (-23.73). Nineteen (19) hybrids showed poor specific combinations for plant height, and had highly significant positive SCA; ICSA91002×ICSR38 (43.25), ICSA89004×ICSR89028 (52.50) and ICSA90001×ICSR89001 (29.61) as examples.
Hybrids ICSA479×Siaya#66-2, ICSA44×Makueni local, ICSA11×S35 and CK60A×IESV 23010 showed highly significant positive specific combination for panicle length. In addition, ICSA11×S35, ICSA645×ICSR153, ICSA11×SP74279 and ICSA9×ICSR56 showed highly significant positive SCA effect for panicle width. Poor specific combiners for both panicle length and width include SDSA4×ICSR 89059, SDSA4×ICSR43, ICSA 90001×ICSR162, ICSA276×ICSR24008, ICSA6×ICSR93034 and ICSA6×IESV23011DL. Only 5 hybrids; ATX623×IESV91104DL, ICSA12×ICSR172, ICSA15×IESV91104 DL, CK60A×KARI MTAMA1 and ICSA12×KARI MTAMA1, had significant positive SCA for grain yield. Three hybrids; ICSA276×IESV91104DL, ICSA15×ICSR 162 and ICSA11×ICSR172 had significant negative SCA for grain yield.

Two hybrids SDSA4×ICSR43 and SDSA4×ICSR59059 had highly significant negative (preferred) SCA for days to 50% flowering. A total of 14 hybrid showed preferred SCA for both days to flowering and mature plant height whereas 7 hybrids were good for days to 50% flowering and grain yield. The hybrid SDSA1×IESV91131DL and SDSA1× BUSIA28-1 possessed desired SCA for days to flowering (negative), height (negative) and grain yield (positive).

The cross ICSA88001× *Macia* and ICSA6×ICSR93034 showed high SCA for yield at Kiboko, and SDSA1× IESV91104DL and SCSA90001×ICSR92003 depicted high SCA for yield at Miwaleni. Two hybrid ICSA12×KARI MTAMA1and ICSA88006×KARI MTAMA1 expressed high SCA effect for yield at Ukiriguru. The highest positive (desired) SCA for panicle length was expressed by the cross ICSA6×IESV23011DL at Miwaleni (10.87) whereas the cross ICSA9×ICSR89058 showed the lowest effect at Kiboko (2.21). The significant positive SCA effect on panicle width ranged from 1.66 at Ukiriguru to 3.10 at Kiboko. The cross ICSA11×S35 had the highest, whereas ICSA11×SP74279 exhibited the lowest SCA effect for the same trait.

CHAPTER FIVE

DISCUSSION

5.1 Phenotypic Diversity of the Selected Sorghum Lines

Significant differences in parental lines for majority of traits evaluated in this study indicates existence of high variability for these traits thus justifying importance of selecting parents for hybrid production. Ultimately, the hybrids also shown significant variation for all these traits making it an ideal material for estimating nature of genetic variation for sugar related as well as productivity traits.

Phenotypic differences recorded in sorghum lines for the agronomic traits evaluated in the present study could be associated with the variations in climatic conditions and soil variability between the three locations. Significant variation in sorghum for yield and yield traits across environments has also been reported by (Warkad et al. 2008). Moreover, the differences in grain yield and its associated traits between environments could be due to location's differences in rainfall during growing season and genotype and soil variability. Kiboko location received relatively higher rainfall than other location resulting in overall high grain yield.

The sorghum lines flowered between 54 to 76 days after sowing. Doggett, (1988) reported 60 to 70 days for most sorghum to flower. For the test agroecologies, early maturing sorghum varieties would be most suitable as they would escape drought which is the major production constraint in the dry and sub-humid environments (Abdulai et al., 2012).

Many male sterile lines studied did not produce tillers; the most tillering male sterile line, ICSB686 produced an average of one tiller per plant across all locations. There was greater tendency for tillering among the R-lines: Teso#15-3 and Teso#17 (Etoroit) produced up to 4 tillers per plant. Similar variation in tillering has been reported by

Hammer et al., (2006). Variation in tillering affects the dynamics of canopy development and hence the timing and nature of crop water limitation (Hammer et al., 2006). Although tillering is significantly less in sorghum it has a major influence on plant leaf area development (Lafarge et al., 2002) and, hence, on crop water use patterns and adaptation to water-limited environments. Generally tillers may contribute to overall yield of a sorghum crop when water supply is not limiting, but profuse tillering is not desirable for dry or sub-humid agroecologies because many tillers would reduce water use efficiency of the sorghum crop.

Tillering is undesirable in A-lines because it can give rise to a range in seed size and maturity in the field. Crop maturity, harvesting and grain quality may be adversely affected if the tillers mature at different times. However, tillering is desirable in R-lines because it gives longer duration of pollen shed (Singh et al., 1997). Teso#15-3 and Teso#17 (etoroit) can serve as valuable sources of genes for high tillering in sorghum breeding programs although they were comparatively low yielders.

Most of the sorghum lines were well exerted with semi compact panicles and semi-loose drooping primary branches which give wide scope for selection to meet farmers' preferences especially in the dry and sub-humid areas. Such variations in panicle shape have been reported by Doggett (1988). Open panicles are preferred for the humid areas to avoid mold and ergot diseases (Doggett, 1988); Singh et al,. 1997)

The significant variations observed in plant pigmentation particularly purple or tan plant type in sorghum foliage has also been reported to associate with resistance to leaf diseases, such as anthracnose (Bupe et al., 1993) and grain colour (Doggett, 1988). Furthermore, purple pigmentation in sorghum plant has been associated with antimicrobial phytoalexin (3-*deoxyanthocyanidins*) (Nicholson et al 1987) as a repellant to insect *Collectrotrichum graminicola* that transmit anthracnose in sorghum. Therefore, this pigmentation in sorghum can facilitate breeding for anthracnose resistant sorghum (Tenkouano et al., 1993).

Restorer lines ICSR37 and IESV91131DL were dwarf materials that could be used in breeding programs for short hybrids as was also found in this study. Shorter sorghums are preferred in dry lowlands as they require relatively shorter period to maturity compared to taller ones. The shorter plant type also withstands lodging and is easier to harvest (Sing et al, (1997). Madhusudhara and Patil (2013) reported wide variations of plant height in sorghum. Tall plants easily lodge but they are beneficial in areas where more priority is for fodder, biomass fuel and thatching.

Most of the sorghums in this study did not develop awns at maturity. Awnless sorghum genotypes are more preferred because of relatively less effort during cleaning. Genotypes, such as IESB2 that expressed poor panicle should not be included in breeding program because the leaf sheath provides favorable conditions for fungi and insects to develop at the base of the panicle hence extend to the whole panicle (Dogget, 1988). Panicle plays an important role in grain yield and clean seed production.

Grain yield in sorghum is influenced by many contributing traits both in positive and negative directions and exhibits low heritability as also reported by Geleta et al., 2005). Therefore, selection indirectly for improved yield is more desirable than direct selection for yield due to its low heritability nature. The highest grain yielder at sub-humid and dry lowland environments was ICSR 24010 and ICSR 683, respectively. These parents form a good source of pollen donors for hybrid sorghum production in the test environments. Additionally, hybrid ATX623 × IESV 91104DL was stable in all the three test sites. Therefore, these sorghum materials could profitably be included in a breeding program in both dry and sub-humid agroecologies.

The significant positive correlation observed among grain yield, percent seed set, days to flowering, productive tillers and panicle length implies that those traits offer high possibility of breeding for high yielding cultivars as also reported by (El Naim et al., 2012). Selection for grain yield also implies selection for traits that are correlated. From the fact that yield is a complex character that depends on many independent contributing characters, the knowledge on type of association between yield and its components will help to simultaneously select for characters associated with yield improvement.

5.1.1 Genotype -by- environment interaction and stability

Relationships among test environments from GGE analysis based on environment focused scaling, that was portrayed to estimate the pattern of environments where sorghum genotypes were tested. The lines that connect the test environments to the biplot origin are called environment vectors. The cosine of the angle between the vectors of two environments approximates the correlation between them. Results revealed that Kiboko and Miwaleni were positively correlated (were at an acute angle), Ukiriguru / Kiboko or Miwaleni were negatively correlated (an obtuse angle).

Moreover, the distance between two environments measures their dissimilarity in discriminating the genotypes (Yan et al. 2000). Thus, the three locations fell into two groups: Kiboko and Miwaleni formed one group, Ukiriguru formed its own group. The presence of close associations among test locations suggests that the same information about the genotypes could be obtained from fewer test locations, and hence the potential to reduce testing cost. If two test locations are closely correlated consistently across years as for the case of Kiboko and Miwaleni, one of them can be dropped without loss of much information about the genotypes. The similarities among these environments could have been brought about by having experienced similar environmental conditions including temperatures, relative humidity and rainfall during the evaluation periods as also reported by Yan and Tinker, (2005).

The polygon view of *which-won-where* for hybrids and parents in this study revealed specific materials for specific environment. The polygon is formed by connecting the markers of the cultivar that are farthest away from the biplot origin such that all other cultivars are contained in the polygon. Cultivars that are located on the vertices of the polygon performed either the best or the poorest in one or more locations (Yan et al. 2000).

The perpendicular lines are equality lines between adjacent genotypes on the polygon which facilitate visual comparison of the genotype. Basing on this information, the hybrid ICSA88001×ICSR93034; R-lines IESV94104DL and IESV 23010DL were promising at both Kiboko and Miwaleni representing dry low lands whereas ICSA15 × IESV91104DL and KARI MTAMA1 were good at Ukiriguru representing sub-humid environments. It is therefore advised to grow ICSA88001×ICSR93034 in Kiboko and Miwaleni, and ICSA15 × IESV91104DL at Ukiriguru. In short, this study shows the possibility of identifying suitable and stable sorghum cultivars under diverse agroecologies by applying a GGE biplot

Considering stability of genotype across agroecologies, the line perpendicular to Average Environmental Coordinate (AEC) in either direction of the GGE biplot measures stability of genotypes in either direction. The genotype that is close to AEC and with shortest perpendicular line is considered stable. Therefore, the hybrid ATX623 × IESV 91104DL and parent IESV 91131DL were stable in all the three test sites. Therefore, these sorghum cultivars could profitably be included in a breeding program in both dry and sub-humid agroecologies. Conversely, ICSA44×IESV91104DL and IESV23010DL had the longest perpendicular line and close to AEC hence unstable and such materials are risky to put in the breeding program (Yan and Kang, 2003).

Sorghum hybrids ATX623×KARI MTAMA1, ICSA12×IESV91104DL, ICSA6×ICSR162, ATX623× IESV91104DL and parents ESV93034, IESV 23014DL and IESV91131DL appeared well adapted and could be considered for testing in many sites aiming for commercial release in Kenyan and Tanzanian dry land and sub-humid agroecologies.

5.2 Performance of experimental hybrids in selected environments

Phenotypic differences were observed in agronomic traits among experimental hybrids and may be partly associated with the variations in climatic conditions between the three locations. This was more pronounced in variations in seed set among the hybrids in the three locations. Relatively lower mean temperatures at Ukiriguru and Miwaleni coupled with high relative humidity could have resulted in the low seed set, similar to the findings of Leland and House (1985). The significant differences observed in fertility restoration among hybrids could be attributed to the specific interaction between the male and female parent genotypes and the environmental influences.

The hybrids that failed to produce seed on the bagged panicles demonstrate that the corresponding male parents in such hybrid were non-restorers (Singh et al. (1997), and could serve as a source of new A-lines. The hybrids that expressed full seed set in some bagged panicles but not others within and across environments gave an indication that the male parents for such hybrids were segregating for fertility restoration, and cannot be used as they are in a breeding program (Murty et al., 1994).

The A-lines A_2DN_{55}, ICSA479 and ICSA469 that produced poor hybrids in terms of seed set irrespective of male parent could be due to the environmental effects and/or the genetic background of the A-line (Sleeper and Poehlman, 2006). Purification through recurrent backcrossing is recommended for these lines before being used for hybrid production. Since these male sterile lines were recently introduced into Africa from different climatic conditions, some could be poorly suited for the new agroecologies. The temperature at the three locations ranged between 18 and 29.3^{o}C which is within the optimum range for most sorghum cultivars (Reddy et al, 2007).

5.3 Heritability and genetic gain of the selected sorghum hybrids

The phenotypic coefficient of variation (PCV) was higher in magnitude than the genotypic coefficient of variation (GCV) for all agronomic traits. There was close similarity between the corresponding estimates of both PCV and GCV for grain yield, days to flowering, plant height and panicle length suggesting that environment had little effect on the expression of these characters (Warkard et al., 2008). It is more likely that environment affected them similarly. The closeness of values for phenotypic and genotypic variances for plant colour and awns at maturity indicates that they are stable as also reported by Falconer and Mackay (1996) and Geleta et al., (2005).

The very high genotypic and phenotypic coefficient of variation across sub-humid and dry lands environments for panicle and number of tillers per plant imply amenability of these traits to improvement through selection (Warkard et al., 2008). Among these characters the difference between PCV and GCV was the highest for midrib colour and tillering which suggested that these traits were more influenced by the environment.

Although, the GCV is indicative of the presence of high degree of genetic variation, the amount of heritable portion of variation can only be determined with the help of estimates of heritability and genetic gain. In general, high heritability accompanied with high expected genetic gain for the characters suggest that the genes governing these characters may have an additive gene effect. High heritability for grain yield indicates potential of the materials in hybrid production (Falconer and Mackay, 1996).

Information on heritability together with expected genetic gain under selection makes it possible to predict expected genetic gain of selecting a particular individual in breeding programs. High heritability coupled with low expected genetic gain expressed in number of days to 50% flowering and panicle shape found in the present study indicated non-additive gene action influences the inheritance of these traits and therefore heterosis breeding approach would be recommended for improvement of the traits. The findings from this study are in agreement with those reported by Sankarapandian et al. (1996).

5.3.1 Heterosis and heterobeltiosis for yield and yield components

Heterosis is manifested through greater vigour of F1s over their parents resulting into higher yields. Heterosis and heterobeltiosis for yield and yield components in most of the sorghum hybrids studied was high and positive, although a few expressed low positive or negative average heterosis and heterobeltiosis. Similar results were reported by Murty et al., (1994). Exploitation of heterosis in grain sorghum has been one of the major success stories in crop improvement research in developed countries. It is well documented that crosses between unrelated, and consequently genetically distant parents, show greater hybrid vigor than crosses between closely related parents (Stuber, 1994). Therefore progress in crop improvement through plant breeding could be boosted by better understanding and an appropriate exploitation of heterosis. Selection of superior parents for outstanding hybrids depend much on heterosis and heterobeltiosis and both are influenced by non-additive gene action (Reif et al., 2007).

The highest positive significant average heterosis and heterobeltiosis for productive tillers was expressed in the cross ICSA687×IESV23011DL. Same cross had relatively high yield. In sorghum, productive tillers contribute to overall grain yield when water supply is not limiting but profuse tillering is undesirable in dry or sub-humid agroecologies because would reduce water use efficiency as also reported by Madhusudhara and Patil, (2013).

In view of heterobeltiosis, the range for panicle length from the present study was 10.6 to 17.1% while that of panicle width was 21.0 to 41.4%. However, Hemlata and Vithal (2006) reported relatively higher heterobeltiosis ranging from 39.6 to 48.4% for panicle length and low, 13.1 to 17.9% for panicle width, respectively. The difference from this study and previous findings could be due to a different set of sorghum materials and environmental conditions used in both studies.

Majority of sorghum hybrids studied showed good average heterosis and heterobeltiosis for panicle exertion (length of peduncle from ligule flag leaf to base of inflorescence). The panicle exertion is an important attribute that often determine the quality of the grains. Overall heterosis and heterobeltiosis ranged from 11.64 to 91.10% and 19.38 to 86.86% respectively which is relatively good as also reported by Dogget, (1988). Poor panicle exertion is disadvantageous because the leaf sheath provides favorable conditions for fungi and insects to develop at the base of the panicle hence extend to the whole panicle.

The number of days to flowering is a very important trait and the negative values of average heterosis and heterobeltiosis are desirable. In this study, the cross combinations that showed desirable negative average heterosis and heterobeltiosis for days to flowering can be exploited in future breeding programs for early maturity hybrid for drought prone areas. It was earlier on reported by Bantilan et al. (2004) that early maturing hybrid sorghum escape terminal drought particularly in rain-fed agriculture typical of east African system. Moreover, early flowering in sorghum provides sufficient time for grain formation. Therefore if a genotype takes too long to reach 50% flowering, the duration of grain filling is also squeezed resulting in low grain yield. Early flowering is highly desirable in sorghum and negative heterosis and heterobeltiosis for this trait is useful.

Superiority of hybrids over mid and better parents for grain yield has been found to be associated with manifestations of heterotic effects in some yield components such as panicle length and width (Sigh et al., 1997). The average heterosis and heterobeltiosis for grain yield in this study varied significantly from cross to cross indicating existence of potential heterosis in parental lines. The highest heterosis for grain yield (81.90%) was expressed in hybrid ICSA11×S35 and ATX623×KARI-MTAMA1. The grain yield heterosis of 88% has been reported by Haussmann et al. (2000) and 69.52% by Hemlata and Vithal (2006). Positive heterobeltiosis for grain yield in the hybrids ICSA11×S35 and ATX623×KARI-MTAMA1 was contributed to by high heterosis for productive number of tillers and panicle length. This calls for exploitation of the heterosis from the germplasm used in the present study to develop hybrid sorghum.

Heterobeltiosis for yield is manifested as the cumulative effect of heterosis for component traits. Most of the hybrids that exhibited positive and significant heterosis for yield also showed it for most of the other component characters as also reported by Jain and Patel (2013). Some of the parents involved in the cross combinations of the selected hybrids were superior for more than one trait. For instance, ATX623 produced hybrid that were good for early maturity and grain yield, whereas ICSA11 produced hybrids that were good for maturity and dwarfness, ICSA12 was good in dwarfness and produced long panicles. IESV91104DL produced hybrids that were good for yield, panicle length and short statured plants; KARI MTAMA1 produced hybrid that were high yielding and short statured plants.

This study showed that heterotic response for yield and its components in a preferred way resulted only in some cross combinations demonstrating the predominant role of non-fixable interactions. Moreover, the present study indicate that heterosis is quick method of increasing sorghum production. With sufficient level of heterosis as found in this research, commercial production of hybrid sorghum would be justified. The identified hybrids in this study could be included in national breeding program in East Africa due to their high production potential.

5.4 General and specific combining abilities of the parent sorghums

Combining ability of the parental lines is important in breeding program because of its close association with *per se* performance of the line (Vinaykumar et al., 2011). It is therefore, necessary to assess genetic potentialities of the parents in hybrid combination through systematic studies in relation to general and specific combining abilities. The combining ability analysis gives an indication of the variation due to general combining ability (GCA) and specific combining ability (SCA), which represent a relative measure of additive and non-additive gene actions, respectively. It is an established fact that dominance is a component of non-additive genetic variance (breeding value). Breeders use these variance components to infer the gene action and to assess the genetic potentialities of the parents in combination. The ultimate choice of parents to be used in a breeding program is determined by per se performance and their behavior in hybrid combination.

In the present study, significant differences in parents and hybrids were recorded, which implied broad genetic diversity of the sorghum materials used in this study. Similar diversity had been reported by Makanda et al. (2012). The difference for the Female × Male interaction in the number of productive tillers, panicle length, panicle width, panicle shape, grain yield indicate high contribution of specific combing ability and therefore predominance of non-additive gene action as also supported by Makanda et al. (2012). Negative GCA and SCA for plant height, days to flowering and positive GCA and SCA for yield and productive tiller is desired for a good genotype. This study found no parent that exhibited high and desired GCA and SCA for all traits evaluated including yield, plant height productive tillers. Some male sterile and restorer lines for early flowering identified from this study including MB6, CK60B, ICSB11, and IESV 23010DL, S35, SP74279 could be favourable for semi-arid areas because they can utilize the limited moisture available and hence escape terminal drought as also reported by Kenga et al.(2004).

The male-sterile lines and restorer lines for plant height that expressed high and negative GCA including ICSB91002, ICSB89004 and ICSB90001; and ICSR24007, ICSR89001 and ICSR38 are potential source of dwarfness genes. They could be used to produce hybrids and varieties that are less susceptible to lodging as also reported by (Singh et al., 1997) and easier to handle for harvesting.

The potential general combiners for productive tillers were ICSB654, ICSB687, and ICSB479 and ICSR153, Siaya#66-2, and IESV23011DL. In addition, the best cross combinations that showed significant and positive SCA for productive tillers per plant were ATX623×Macia, ICSA88001×ICSR93034 and ICSA90001×ICSR162. Tillering is generally among important traits affecting accumulation of biomass and ultimately grain yield in sorghum. Hammer et al., (1996) reported significant yield advantage of high-tillering sorghum types when water was plentiful, whereas such types incurred a significant disadvantage under water-limited circumstances. Generally, tillering is undesirable in sorghum male sterile lines as this give rise to a range in seed size and maturity in the field but it is desirable in pollen parent (restorers) as this gives a longer duration of pollen shed, as stated by Singh et al., 1997.

High and significant GCA recorded on panicle width and length for the male sterile lines ICSB687, ICSB88001, SDSB4, ICSB90001, ICSB88001, ICSB89004 and ICSB293 indicates that they were the best general combiners for panicle width and length. Basing on the same traits for the restorers, ICSR24008, IESV23011 and ICSR93034 had positive and significant GCA effect therefore best general combiners for panicle width and length across environments. Panicle characteristics including length, width and shape is positively related to the final yield in sorghum as also reported by Can et al., (1997). Long, broad and compact panicles are more preferred as they results into higher yields compared to their counterparts.

Panicle exertion is an important attribute for clean seed in sorghum. The genotypes that expressed negative of GCA for panicle exertion for example ICSB479 should be avoided in breeding program. Specific combining ability for panicle exertion revealed that ICSA376×IESV23013 was the best hybrid among others as it expressed high negative values. Negative GCA for panicle exertion is undesired (Dogget, 1988), because the leaf sheath provides favorable conditions for fungi and insects to develop at the base of the panicle hence extend to the whole panicle. In contrary sorghum genotypes that showed high and positive GCA for panicle exertion for example MB6 is the best source breeding material for well exerted-panicle sorghum hybrids.

The negative combining ability for the days to flowering is desirable as it is associated with earliness in sorghum (Makanda et al., 2012). Early maturing sorghum hybrids and parental lines can escape terminal drought in the dry agroecologies where moisture is the limiting factor to crop production. Breeding and selection of early-maturing varieties possessing better yield has been considered as a possible option to mitigate the drastic effect of drought stress (House, 1997).

On the other hand, the best specific combiner for days to flowering was expressed in some cross hybrids including SDSA4×ICSR89059, SDSA4×ICSR43, SDSA1×ICSR43, ICSA479×Siaya#66-2 and ICSA90001×ICSR89001 implying that these cross combinations matures early. Their SCA were highly negative and significant indicative of early maturity trait. Similar results have been reported by Makanda et al. (2012).

The best general combiners for grain yield were ICSB293, ICSB6, ICSB15 and BTX623, for female lines, and ICSR23019, Tegemeo, IESV91104DL and KARI MTAMA1 for restorers. In general, the means from all locations indicate that line ICSB687 expressed significant negative (desired) GCA effects for four traits viz days to 50% flowering, mature plant height, panicle length and panicle width. This parent could be utilized as a source of breeding lines for both dry lands and sub-humid areas.

The present study revealed the existence of considerable positive SCA for yield in five crosses which included ATX623×IESV91104DL, ICSA12×ICSR172, ICSA15×IESV91104DL, CK60A×KARI MTAMA1 and ICSA12×KARI MTAMA1. These hybrids could be employed in dry land and sub-humid areas of east Africa for improved yields.

The parents that expressed high positive GCA for grain yield and negative for days to flowering and height were considered good combiners (Can et al., 1997). The positive effect to the two traits does not have bad implications on synchrony to flowering and pollen to recipient sterile lines. According to Singh et al. (1997), the male parents that flower 4-6 days later than the corresponding female parents are preferred for sorghum hybrid production; and the difference in height between male and female lines should be about 30 cm. Generally, performance of a hybrid is related to the performance of its parents (Murty et al., 1994). There is high potential for breeding high grain yield sorghum that are well suited to dry land and sub-humid areas of east Africa basing on the information on phenotypic expression and general and specific combining abilities developed in this study.

Two papers were published from this study as follows:-

1. Ringo et al., (2015). Heterosis for yield and its components in sorghum (Sorghum bicolor L. Moench) hybrids in dry lands and sub-humid environments of East Africa: *Australian Journal of Crop Science*: Vol. 9 No.1: 9-13

2. Justin et al., (2015). Combining Ability of Some Sorghum Lines for Dry lands and Sub-Humid Environments of East Africa: *African Journal of Agricultural Research,* Vol. 10 (19): 2048-2060

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. Sorghum collections held at ICRISAT are highly diverse.

2. High yielding hybrids were developed from ICRISAT collections but with significant variation in performance between locations. Kiboko and Miwaleni sites gave relatively similar results.

3. There was high heritability coupled with low expected genetic gain expressed in some hybrids with high heterosis

4. Some hybrids expressed high levels of average heterosis, heterobeltiosis whereas some parental lines demonstrated high and desirable general and specific combining abilities for yield stability across test environments.

6.2 Recommendation and Future areas of research

1. Genotypes IESV91104DL and IESV91131DL are recommended for dry lowlands whereas IESV23019 and KARI MTAM1 are best suitable for sub-humid environments.

2. Hybrids ICSA15×IESV91104DL, CSA12×IESV91104DL and ICSA88006× KARI MTAMA1 are recommended for the Sub-humid environments; whereas ATX623×IESV91104DL, ATX623×KARI MTAMA1 and ICSA88001× ICSR93034 for areas with limited rainfall.

3. Cross combinations ICSA44×IESV91104DL, ICSA15×IESV91104DL, ATX623×IESV 91104DL, ICSA12×KARI MTAMA1, ICSA366×KARI MTAMA1, ICSA11×S35 and parental lines KARI-MTAMA1, IESV91104DL, S35, ATX623, ICSA12, ICSA11 could be deployed for general yield improvement programs in sorghum growing areas of East Africa.

4. Future breeding activity requiring phenotypic characterization and selection for dry low land conditions should not involve both, Kiboko and Miwaleni at the same time, one of the two sites can give enough information

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APPENDICES

Appendix I. List and selected properties of sorghum lines used in this study

S/no	B-lines	Origin	Status	S/no	B-lines	Origin	Status	S/no	R-lines	Origin	Status
1	B2 DN55	ICRISAT-India	Inbred line	21	ICSB 686	ICRISAT-India	Inbred line	40	ICSR 108	ICRISAT -India	Inbred line
2	BTX 623	ICRISAT-India	Inbred line	22	ICSB 687	ICRISAT-India	Inbred line	41	ICSR 153	ICRISAT -India	Inbred line
3	CK 60B	ICRISAT-India	Inbred line	23	ICSB 73	ICRISAT-India	Inbred line	42	ICSR 160	ICRISAT -India	Inbred line
4	ICSB 11	ICRISAT-India	Inbred line	24	ICSB 77	ICRISAT-India	Inbred line	43	ICSR 162	ICRISAT -India	Inbred line
5	ICSB 12	ICRISAT-India	Inbred line	25	ICSB 88001	ICRISAT-India	Inbred line	44	ICSR 165	ICRISAT -India	Inbred line
6	ICSB 15	ICRISAT-India	Inbred line	26	ICSB 88006	ICRISAT-India	Inbred line	45	ICSR 172	ICRISAT -India	Inbred line
7	ICSB 276	ICRISAT-India	Inbred line	27	ICSB 89003	ICRISAT-India	Inbred line	46	ICSR 196	ICRISAT -India	Inbred line
8	ICSB 293	ICRISAT-India	Inbred line	28	ICSB 9	ICRISAT-India	Inbred line	47	ICSR 24001	ICRISAT -India	Inbred line
9	ICSB 324	ICRISAT-India	Inbred line	29	ICSB 90001	ICRISAT-India	Inbred line	48	ICSR 24003	ICRISAT -India	Inbred line
10	ICSB 366	ICRISAT-India	Inbred line	30	ICSB 91002	ICRISAT-India	Inbred line	49	ICSR 24004	ICRISAT -India	Inbred line
11	ICSB 371	ICRISAT-India	Inbred line	31	IESB 2	ICRISAT-India	Inbred line	50	ICSR 24005	ICRISAT -India	Inbred line
12	ICSB 376	ICRISAT-India	Inbred line	32	MB 6	ICRISAT-India	Inbred line	51	ICSR 24006	ICRISAT -India	Inbred line
13	ICSB 44	ICRISAT-India	Inbred line	33	SDSB 1	ICRISAT-India	Inbred line	52	ICSR 24007	ICRISAT -India	Inbred line
14	ICSB 452	ICRISAT-India	Inbred line	34	SDSB 29	ICRISAT-India	Inbred line	53	ICSR 24008	ICRISAT -India	Inbred line
15	ICSB 469	ICRISAT-India	Inbred line	35	SDSB 4	ICRISAT-India	Inbred line	54	ICSR 24009	ICRISAT -India	Inbred line
16	ICSB 479	ICRISAT-India	Inbred line		**R-lines**	**Origin**	**Status**	55	ICSR 24010	ICRISAT -India	Inbred line
17	ICSB 592	ICRISAT-India	Inbred line	36	Busia #28-1	ICRISAT-Nairobi	Inbred line	56	ICSR 37	ICRISAT -India	Inbred line
18	ICSB 6	ICRISAT-India	Inbred line	37	Busia #38(Sabina)	ICRISAT-Nairobi	Landrace	57	ICSR 38	ICRISAT -India	Inbred line
19	ICSB 654	ICRISAT-India	Inbred line	38	BUSIA# 17-3	ICRISAT-Nairobi	Landrace	58	ICSR 43	ICRISAT -India	Inbred line
20	ICSB 683	ICRISAT-India	Inbred line	39	Chitichi	ICRISAT-Nairobi	Landrace	59	ICSR 56	ICRISAT -India	Inbred line

Appendix I Continued

S/no	R-lines	Origin	Status	S/no	R-lines	Origin	Status	S/no	R-lines	Origin	Status
60	ICSR 89001	ICRISAT -India	Inbred line	81	IESV 23012 DL	ICRISAT -India	Inbred line	102	SIAYA # 66-2	ICRISAT-Nairobi	Landrace
61	ICSR 89028	ICRISAT -India	Inbred line	82	IESV 23013 DL	ICRISAT -India	Inbred line	103	SIAYA # 78	ICRISAT-Nairobi	Landrace
62	ICSR 89058	ICRISAT -India	Inbred line	83	IESV 23014 DL	ICRISAT -India	Inbred line	104	SIAYA # 81-2	ICRISAT-Nairobi	Landrace
63	ICSR 89059	ICRISAT -India	Inbred line	84	IESV 23018 DL	ICRISAT -India	Inbred line	105	SIAYA # 93-1	ICRISAT-Nairobi	Landrace
64	ICSR 89068	ICRISAT -India	Inbred line	85	IESV 23019 DL	ICRISAT -India	Inbred line	106	SIAYA # 97-1	ICRISAT-Nairobi	Landrace
65	ICSR 90017	ICRISAT -India	Inbred line	86	IESV 91104 DL	ICRISAT -India	Inbred line	107	SIAYA #46-1	ICRISAT-Nairobi	Landrace
66	ICSR 92003	ICRISAT -India	Inbred line	87	IESV 91131 DL	ICRISAT -India	Inbred line	108	SP 74268	ICRISAT-India	Inbred line
67	ICSR 93001	ICRISAT -India	Inbred line	88	IESV 92170 DL	ICRISAT -India	Inbred line	109	SP 74276	ICRISAT-India	Inbred line
68	ICSR 93034	ICRISAT -India	Inbred line	89	IESV189	ICRISAT -India	Inbred line	110	SP 74277	ICRISAT-India	Inbred line
69	ICSV 189	ICRISAT -India	Inbred line	90	IS 11167	ICRISAT -India	Inbred line	111	SP 74278	ICRISAT-India	Inbred line
70	ICSV 574	ICRISAT -India	Inbred line	91	IS 8884	ICRISAT -India	Inbred line	112	SP 74279	ICRISAT-India	Inbred line
71	ICSV 93048	ICRISAT -India	Inbred line	92	KARI MTAMA1	ICRISAT-Nairobi	Variety	113	SP 74280	ICRISAT-India	Inbred line
72	ICSV 95022	ICRISAT -India	Inbred line	93	*Macia*	ICRISAT-Nairobi	Variety	114	SPL 9B	ICRISAT-India	Inbred line
73	ICSV 95023	ICRISAT -India	Inbred line	94	Makueni local	ICRISAT-Nairobi	Landrace	115	Tegemeo	ICRISAT-Nairobi	Variety
74	ICSV 95046	ICRISAT -India	Inbred line	95	Nakhadabo	ICRISAT-Nairobi	Landrace	116	Teso #17(Etoroit)	ICRISAT-Nairobi	Landrace
75	IESV 23005 DL	ICRISAT -India	Inbred line	96	S 35	ICRISAT-Nairobi	Inbred line	117	TESO # 11_2	ICRISAT-Nairobi	Landrace
76	IESV 23006DL	ICRISAT -India	Inbred line	97	SERENA	ICRISAT-Nairobi	Variety	118	TESO # 15-3	ICRISAT-Nairobi	Landrace
77	IESV 23007 DL	ICRISAT -India	Inbred line	98	SIAYA # 27-3	ICRISAT-Nairobi	Landrace	119	TESO # 17-2	ICRISAT-Nairobi	Landrace
78	IESV 23008 DL	ICRISAT -India	Inbred line	99	SIAYA # 42	ICRISAT-Nairobi	Landrace	120	WAGITA	ICRISAT-Nairobi	Landrace
79	IESV 23010 DL	ICRISAT -India	Inbred line	100	SIAYA # 46-2	ICRISAT-Nairobi	Landrace	121	ZSV 3	ICRISAT-Nairobi	Variety
80	IESV 23011 DL	ICRISAT -India	Inbred line	101	SIAYA # 50-3	ICRISAT-Nairobi	Landrace				

Appendix II. Rating scale for seed set of sorghum hybrids at Kiboko and Miwaleni in 2010 season

Seed set Range (%)	Description
100	The whole head is filled with grain seed set
80 to <100	Seed set above three quarters of head
60 to <80	Just above two thirds of the head showing seed set
40 to <60	Half of the total head showing seed set
20 to <40	About a quarter of the head showing seed set
1 to <20	Less than a quarter of the head showing seed set
0	Total sterility, no seed set on the head

Adopted from IPGRI, 1993

Appendix III. General Performance of sorghum lines evaluated across Kiboko, Miwaleni and Ukiriguru between 2011-2012 growing seasons

No	Entry	DAF	HT (cm)	PC	TL	PS	PE (cm)	PL (cm)	PW (cm)	AW	G C	Y(t/ ha)
1	IESB 2	69.0	111.8	2.0	0.0	5.0	0.6	26.4	7.6	0.0	1.0	2.3
2	B2 DN 55	66.0	108.7	1.0	0.0	6.0	14.8	23.1	6.0	0.0	1.0	1.5
3	BTX623	67.0	134.8	2.0	0.0	6.0	6.6	27.8	6.6	0.0	1.0	1.9
4	BUSIA # 17-3	75.0	223.4	2.0	0.0	4.0	6.4	14.8	7.3	0.0	2.0	1.6
5	BUSIA # 28-1	71.0	203.4	2.0	0.0	6.0	3.2	12.4	7.7	0.0	3.0	1.2
6	BUSIA38(Sabna)	76.0	231.6	2.0	2.0	6.0	1.3	20.4	7.7	0.0	2.0	0.6
7	CHITICHI	54.0	161.1	2.0	0.0	5.0	13.3	22.2	6.2	0.0	1.0	0.0
8	CK60B	65.0	112.5	2.0	0.0	6.0	10.4	22.3	5.5	0.0	1.0	1.7
9	ICSB 11	65.0	124.1	1.0	0.0	6.0	8.1	26.4	5.6	0.0	2.0	1.8
10	ICSB 12	68.0	130.8	1.0	0.0	6.0	4.9	32.9	7.0	0.0	1.0	2.3
11	ICSB 15	68.0	116.5	1.0	0.0	6.0	5.1	30.7	6.2	0.0	1.0	2.2
12	ICSB 276	69.0	173.1	1.0	0.0	5.0	12.8	31.8	7.9	0.0	1.0	3.3
13	ICSB 293	71.0	154.3	1.0	0.0	6.0	10.6	29.6	6.3	0.0	1.0	1.9
14	ICSB 324	71.0	180.2	1.0	0.0	5.0	9.7	30.4	8.2	0.0	1.0	2.4
15	ICSB 376	67.0	166.7	2.0	0.0	6.0	7.2	26.2	5.9	0.0	2.0	2.0
16	ICSB 452	71.0	146.9	1.0	0.0	6.0	4.6	27.5	6.6	0.0	1.0	2.0
17	ICSB 469	72.0	142.9	1.0	0.0	6.0	3.3	28.2	7.3	0.0	2.0	1.9
18	ICSB 479	68.0	178.1	1.0	0.0	6.0	4.2	19.0	6.9	1.0	2.0	2.0
19	ICSB 592	71.0	169.7	1.0	0.0	6.0	3.5	31.3	7.0	0.0	2.0	2.5
20	ICSB 686	64.0	123.5	1.0	1.0	6.0	7.4	24.1	6.6	1.0	1.0	1.9
21	ICSB 687	66.0	139.2	1.0	0.0	5.0	4.7	25.0	7.2	0.0	2.0	2.1
22	ICSB 88001	72.0	150.7	1.0	0.0	5.0	2.1	29.2	6.8	0.0	2.0	2.1
23	ICSB 88006	71.0	113.8	1.0	0.0	6.0	10.6	30.3	5.9	0.0	1.0	2.1
24	ICSB 89003	66.0	120.7	1.0	0.0	6.0	9.4	28.4	5.9	0.0	1.0	1.5
25	ICSB 9	66.0	120.6	1.0	0.0	5.0	7.9	28.2	6.2	0.0	2.0	1.7
26	ICSB 90001	72.0	135.8	1.0	0.0	5.0	2.0	30.4	8.6	0.0	2.0	1.8
27	ICSB 91002	67.0	116.5	2.0	0.0	6.0	5.3	27.3	6.0	0.0	2.0	1.3
28	ICSR 160	71.0	159.3	1.0	0.0	5.0	3.2	28.3	7.5	0.0	2.0	2.3
29	ICSR 24005	72.0	128.5	1.0	0.0	6.0	4.7	28.0	6.7	0.0	1.0	1.4
30	ICSR 24006	72.0	180.7	1.0	0.0	6.0	3.8	31.0	7.1	0.0	2.0	2.0
31	ICSR 24007	75.0	130.7	1.0	0.0	6.0	3.6	26.7	6.5	0.0	2.0	2.2
32	ICSR 24009	71.0	155.0	1.0	0.0	6.0	2.0	27.7	7.2	0.0	2.0	2.1
33	ICSR 24010	68.0	215.8	1.0	0.0	5.0	6.4	22.4	8.1	0.0	2.0	1.6
34	ICSR 37	68.0	115.7	1.0	0.0	6.0	3.1	22.8	5.8	0.0	1.0	1.4
35	ICSR 38	70.0	135.4	1.0	0.0	6.0	2.1	26.7	8.1	0.0	2.0	1.8
36	ICSR 43	73.0	148.4	1.0	0.0	5.0	1.7	30.4	7.2	0.0	2.0	1.9
37	ICSR 56	67.0	146.3	1.0	0.0	6.0	5.6	24.3	6.3	0.0	2.0	1.6
38	ICSR 89001	73.0	128.5	1.0	0.0	7.0	2.7	30.2	7.0	0.0	2.0	2.1
39	ICSR 93034	73.0	141.3	1.0	0.0	6.0	3.9	30.3	8.5	0.0	2.0	3.5
40	ICSR 90017	70.0	233.8	1.0	0.0	7.0	3.8	17.9	7.0	0.6	1.0	1.6
41	ICSR 93001	70.0	148.3	1.0	0.0	6.0	3.6	27.1	7.3	0.0	1.0	2.1
42	ICSR 89028	69.0	209.4	1.0	0.0	6.0	3.2	26.6	8.2	0.0	2.0	2.6
43	ICSR153	69.0	153.4	1.0	0.0	6.0	3.9	30.1	7.1	0.0	2.0	1.7
44	ICSV 95022	69.0	131.8	1.0	0.0	5.0	1.7	30.9	9.1	0.0	2.0	2.2
45	ICSV 95023	63.0	145.9	1.0	0.0	5.0	6.4	25.3	6.0	0.0	2.0	1.0
46	ICSV 95046	69.0	143.9	2.0	0.0	4.0	1.9	30.6	10.0	0.0	2.0	1.7
47	ICSV 189	71.0	152.4	1.0	0.0	7.0	6.4	23.8	6.9	0.3	2.0	2.1
48	ICSV 574	74.0	204.4	1.0	0.0	6.0	2.1	23.3	7.9	0.0	1.0	2.4
49	IESV 23005 DL	64.0	168.4	1.0	0.7	6.0	7.9	24.8	7.3	0.0	2.0	2.1
50	IESV 23006 DL	68.0	169.5	1.0	0.6	5.0	4.5	26.6	8.5	0.0	2.0	2.2
	SEM:	0.8	5.8	0.1	0.0	0.3	1.1	0.9	0.4	0.1	0.2	0.4
	GM:	69.0	162.4	1.4	0.5	6.2	5.1	25.3	7.0	0.1	2.2	1.9
	LSD:	2.3	16.1	0.2	0.4	0.8	3.3	2.5	1.2	0.1	0.6	1.1
	CV	2.9	8.8	18.1	127	12.4	60.2	8.9	16.7	139	25	20.2

Appendix III continues

No	Entry	DAF	HT (cm)	PC	TL	PS	PE (cm)	PL (cm)	PW (cm)	AW	GC	Y(t/ha)
51	IESV 23007 DL	67.0	168.3	1.0	0.6	6.0	6.7	26.9	7.6	0.0	2.6	2.0
52	IESV 23008 DL	66.0	151.2	1.2	0.0	6.3	3.8	23.9	7.5	0.0	3.1	2.3
53	IESV 23010 DL	62.0	153.7	1.0	0.0	5.7	5.3	24.0	7.5	0.0	2.6	1.8
54	IESV 23011 DL	69.0	185.9	2.0	0.0	4.9	7.4	31.1	8.8	0.8	2.3	2.2
55	IESV 23012 DL	68.0	144.1	1.8	0.0	5.0	5.7	30.0	7.8	1.0	2.3	2.0
56	IESV 23014 DL	70.0	122.7	2.0	0.0	4.7	1.9	32.5	8.8	0.8	2.6	2.0
57	IESV 23019 DL	69.0	173.5	1.8	0.0	5.3	1.7	32.4	8.4	1.0	2.9	1.7
58	IESV 91104 DL	69.0	194.8	1.0	0.0	6.6	4.8	23.6	8.1	0.0	1.7	2.6
59	IESV 91131 DL	70.0	122.4	1.0	0.0	6.8	1.4	26.5	7.6	0.0	1.7	2.0
60	IESV 92170 DL	65.0	174.7	1.7	0.0	4.9	11.3	27.3	7.3	0.0	2.5	1.7
61	IS 11167	75.0	303.0	2.0	0.0	7.7	10.4	15.1	7.2	0.6	3.2	1.0
62	IS 8884	69.0	208.1	1.8	0.0	7.8	4.0	10.7	5.9	0.0	2.8	1.7
63	KARIMTAMA1	67.0	168.6	1.0	0.0	6.6	4.0	24.7	7.9	0.0	1.7	3.3
64	Makueni local	66.0	232.6	2.0	2.0	4.1	7.2	21.4	9.2	0.0	2.9	1.7
65	MB 6	63.0	108.6	1.0	0.0	6.9	12.9	23.5	5.2	0.0	1.7	1.0
66	MR # 22x IS 8613/2/3-1-3	68.0	147.0	1.2	0.6	6.9	1.7	20.4	6.3	0.0	2.6	1.3
67	Nakhadabo	71.0	226.0	1.8	0.5	6.5	2.8	14.6	8.9	0.0	2.3	1.5
68	S 35	62.0	161.7	1.0	0.0	6.2	4.9	22.7	7.2	0.0	1.7	1.4
69	SDSB 1	70.0	130.4	1.7	0.0	6.9	3.9	32.3	5.8	0.0	2.0	1.5
70	SDSB 29	70.0	151.1	2.0	0.0	6.8	2.5	28.7	5.9	0.0	1.7	2.0
71	SDSB 4	70.0	129.0	1.5	0.0	6.6	2.9	30.7	6.0	0.5	1.4	1.7
72	SERENA	66.0	148.2	2.0	0.6	6.3	0.7	26.2	7.2	0.0	2.8	1.6
73	SIAYA # 27-3	70.0	158.7	2.0	3.0	7.5	1.5	21.6	6.5	0.0	3.2	1.8
74	SIAYA # 42	70.0	168.8	2.0	4.0	7.6	2.5	19.3	6.2	0.0	2.9	2.1
75	SIAYA # 46-1	70.0	154.6	1.8	0.4	6.5	0.7	22.8	6.8	0.0	3.4	1.5
76	SIAYA # 46-2	70.0	178.2	2.0	0.5	7.6	0.8	22.5	6.3	0.0	3.1	1.9
77	SIAYA # 50-3	67.0	163.4	2.0	0.5	7.1	1.1	23.4	6.7	0.0	3.4	2.0
78	SIAYA # 81-2	68.0	172.8	2.0	2.0	6.6	1.6	24.6	6.9	0.0	3.4	1.5
79	SIAYA # 93-1	67.0	185.1	2.0	0.6	7.5	2.4	23.7	6.9	0.0	3.2	2.2
80	SIAYA # 97-1	74.0	270.7	1.0	2.0	7.5	7.2	16.7	6.2	0.0	2.0	2.1
81	SP 74268	67.0	198.9	1.7	0.6	5.0	14.4	32.7	7.3	0.0	2.6	1.8
82	SP 74276	67.0	131.1	1.2	0.4	6.6	6.0	22.5	6.6	0.0	2.6	0.3
83	SP 74277	67.0	127.5	1.0	0.5	7.1	8.8	22.6	5.9	0.0	2.5	1.2
84	SP 74278	68.0	151.9	1.0	0.4	6.6	6.9	26.6	7.0	0.0	2.6	1.7
85	SP 74279	69.0	149.0	1.0	0.4	6.6	5.8	26.5	7.0	0.0	2.3	1.7
86	SP 74280	68.0	144.1	1.2	0.4	6.6	8.7	20.7	6.4	0.0	2.6	1.3
87	TESO # 11-2	66.0	170.5	1.8	0.6	4.9	7.5	29.8	7.0	0.0	2.0	1.3
88	TESO # 15-3	71.0	245.7	1.8	3.0	5.4	2.7	23.7	6.2	0.0	1.7	1.5
89	TESO 17(Etoroit)	74.0	240.4	2.0	0.8	5.4	3.0	22.1	6.3	0.0	2.6	1.6
90	TESO17-2 (Etoroit)	74.0	232.9	1.8	2.0	5.4	5.1	23.1	6.5	0.0	2.6	1.5
91	ZSV 3	62.0	178.1	1.8	0.8	7.2	9.3	18.5	6.5	0.0	2.3	1.9
92	MACIA	68.0	125.1	1.2	0.5	6.6	4.3	25.5	7.1	0.0	2.3	1.8
93	TEGEMEO	68.0	151.8	1.0	0.6	6.3	2.6	22.1	7.7	0.0	2.0	2.0
94	WAGITA	71.0	226.5	2.0	3.0	6.0	3.9	19.1	8.8	0.0	2.8	1.7
	SEM:	0.9	5.8	0.1	0.2	0.3	1.2	0.9	0.4	0.1	0.2	0.4
	GM:	69.2	162.4	1.4	0.6	6.2	5.1	25.3	7.1	0.1	2.3	1.9
	LSD:	2.4	16.2	0.3	0.5	0.8	3.3	2.5	1.2	0.1	0.6	1.1
	CV	2.9	8.9	18.2	127.8	12.5	60.2	8.9	16.8	139.3	25.2	20.2

Appendix IV. Mean performance of sorghum lines at Ukiriguru during 2011-2012 growing seasons

No	Entry	DAF	HT(cm)	P C	TL	PL (cm)	PW (cm)	PE (cm)	A W	G C	Y (t/ha)
1	KARI MTAMA 1	75	135.75	2	2.11	23.02	8.31	4.96	0	3	4.3
2	IESV 23019 DL	72	175.3	2	2.6	31.0	9.6	5.3	1	3	3.8
3	ICSR 24010	67	202.18	1	0.73	23.8	10.05	9.18	0	3	3.5
4	SP 74278	71	140.1	1	0.55	24.88	6.05	14.75	0	3	2.7
5	SP 74277	67	112.85	1	1.4	21.85	5.7	14.38	0	3	2.5
6	ICSR 162	78	193.54	1	1.94	22.49	8.73	7.39	0	3	2.3
7	IESV 23014 DL	77	113.75	2	2.9	29.8	8.95	5.8	1	3	2.3
8	IESV 23007 DL	73	148.05	1	2.15	26	9.75	7.2	0	2	2.2
9	ICSB 88006	72	116.7	1	2.03	29.88	5.88	16.3	0	2	2.2
10	ICSB 88001	77	142.78	1	1.53	30.15	8.8	4.75	1	2	2.2
11	ICSB 366	70	129.69	1	1.7	22.06	6.01	14.91	0	2	2.3
12	ICSB 592	78	149.78	1	2.7	30.2	7.13	3.6	0	3	2.2
13	ICSB 324	72	172.55	1	1.7	30.4	9.88	13.63	0	2	1.9
14	ICSR 37	73	109.5	1	1.65	21.48	5.33	6.75	0	2	1.8
15	ICSV 95023	73	136.35	1	1.48	25.75	8.05	8.43	0	3	1.7
16	ICSB 73	71	144.76	1	0.6	21.16	7.58	8.08	0	2	1.5
17	IESV 23010 DL	69	136.25	1	2.85	22.58	8.5	12.83	0	3	1.5
18	ICSR 89068	75	126.42	1	3.4	23.32	6.58	6.24	0	3	1.5
19	IESV 23012 DL	74	125.7	2	3.2	31.5	9.93	8.18	1	4	1.3
20	ICSR 160	72	239.53	2	2.01	24.13	9.87	4.27	1	1	1.4
21	ICSB 469	76	123.85	1	1.5	28.53	10.13	4.58	0	3	1.4
22	SERENA	70	138.4	2	1.88	22.85	7.55	3.95	0	3	1.3
23	ICSB 452	72	124.38	1	1.75	26.38	6.93	3.3	1	2	1.3
24	WAGITA	73	193.22	2	0.94	20.16	13.14	5.71	0	4	1.3
25	ICSB 654	65	123.56	1	3.4	21.39	4.64	18.71	0	3	1.1
26	ICSB 12	71	123.75	1	2.05	31.05	8	10.08	0	2	1.1
27	ICSR 24005	68	125.9	1	1.55	27.7	7.78	6.38	0	2	1.6
28	SP 74268	72	190.35	2	1.93	31.2	10.3	20.25	0	3	1.6
29	ICSR 153	74	150.85	1	1.28	30.78	8.63	9.3	0	3	1.6
30	IESV 23008 DL	71	137	1	2.8	22.6	7.7	11.9	0	3	1.5
31	ICSB 686	70	121.25	1	3.55	22.85	6.98	7.9	1	2	1.5
32	ICSR 108	78	114.16	1	0.56	28.26	10.82	4.73	0	1	1.5
33	IESV 92170 DL	73	163.95	2	1.75	25.75	9.1	17.58	0	3	1.5
34	SPL 9B	70	101.49	2	1.63	25.66	7.61	8.38	1	2	1.5
35	S 35	69	152.1	1	2.08	22.18	7.68	9.48	0	2	1.4
36	B2 DN55	68	100.5	1	3.43	18.83	5.85	20.48	0	2	1.4
37	CK 60B	70	113.24	1	2.84	20.09	6.53	22.14	0	3	1.3
38	ICSR 38	69	117.3	1	0.8	25.25	9.03	5.63	0	3	1.3
39	ICSR 196	74	135.38	1	1.04	27.28	7.94	2.9	0	2	1.4
40	IESV 23011 DL	76	174.53	2	2.2	31.03	11.45	10.63	1	3	1.4
41	BUSIA# 17-3	81	206.55	2	1.68	13.95	7.88	2.11	0	2	1.2
42	SIAYA # 46-2	78	168.92	2	1.69	22.58	7.46	2.04	0	4	1.4
43	TESO # 17 (ETOROIT)	73	206.16	2	3.06	23.96	7.72	1.43	0	2	1.3
44	SP 74280	70	131.2	1	0.55	19.55	5.4	13.38	0	3	1.4
45	IESV 23013 DL	69	159.4	2	1.85	29.85	9.6	7.88	1	3	1.1
46	ICSR 56	69	139.53	1	2.7	22.78	6.55	10.65	0	3	1.4
47	ICSR 93001	73	137.65	1	1.73	26	6.5	5.78	0	2	1.4
48	ICSB 479	75	145.45	1	1.25	18.15	7.1	6.98	1	3	1.1
49	ICSB 90001	74	135	1	0.68	31.03	11.93	4.18	0	3	1.1
50	ICSR 89058	76	137.18	1	0.74	28.05	6.74	2.73	0	2	1
	Overal Mean	**73**	**147.06**	**1**	**2.0**	**24.7**	**8.2**	**8.4**	**0**	**3**	**1.9**
	CV%	**6.96**	**9.21**	**6**	**28.9**	**9.7**	**23.3**	**33.7**	**13**	**27**	**16.3**
	LSD	**72.6**	**76.8**	**2**	**3.1**	**18.5**	**7.8**	**20.5**	**0**	**2**	**4.6**

Appendix IV continues

No	Entry	DAF	HT(cm)	PC	TL	PL (cm)	PW (cm)	PE (cm)	AW	GC	Y (t/ha)
51	SIAYA # 78	69.0	244.0	2.0	2.7	26.3	17.5	4.9	0.0	4.0	2.2
52	IESV 91104 DL	76.7	145.9	1.0	1.2	33.2	10.2	5.5	0.0	3.0	2.1
53	IESV 23018 DL	75.1	116.2	2.0	2.1	32.2	8.3	3.3	1.0	3.0	2.1
54	SP 74279	75.6	132.6	1.0	0.6	25.0	6.4	16.1	0.0	2.0	2.0
55	BTX 623	67.9	121.0	2.0	2.1	27.3	6.5	12.7	0.0	2.0	2.5
56	ICSB 11	69.1	110.9	1.0	1.5	21.9	5.6	14.7	0.0	3.0	1.9
57	SIAYA #46-1	80.7	149.2	2.0	0.7	21.6	7.2	2.3	0.0	4.0	1.8
58	IS 8884	66.1	180.9	2.0	1.4	11.4	6.6	5.0	0.0	3.0	1.8
59	ICSB 6	74.1	101.1	1.0	3.2	27.5	7.2	5.2	0.0	2.0	2.5
60	MAKUENI LOCAL	71.9	222.1	2.0	2.3	20.8	13.2	5.9	0.0	4.0	1.8
61	ICSV 189	73.9	145.5	1.0	2.1	23.5	7.0	13.9	1.0	3.0	2.5
62	ICSR 93034	72.7	188.6	1.0	1.8	26.1	10.3	4.0	0.0	3.0	2.5
63	MB 6	72.1	106.0	1.0	1.7	21.1	4.9	18.8	0.0	2.0	1.4
64	IESV 23005 DL	71.9	148.6	1.0	2.7	22.2	7.7	16.4	0.0	3.0	2.5
65	ICSV 574	75.9	171.4	1.0	1.6	23.1	10.0	3.0	0.0	2.0	2.5
66	ICSR 89059	71.3	164.7	1.0	0.8	30.1	9.1	8.4	0.0	4.0	2.0
67	ICSB 15	69.6	110.9	1.0	1.1	27.1	6.4	8.8	0.0	2.0	2.5
68	IS 11167	77.3	253.6	2.0	1.4	16.1	8.3	14.0	1.0	3.0	2.5
69	ICSB 44	74.4	109.2	1.0	1.1	24.0	5.8	6.9	0.0	3.0	2.5
70	BUSIA #38 (SABINA)	75.3	150.0	2.0	2.6	22.6	9.2	5.4	0.0	2.0	1.5
71	TESO # 17-2	76.1	201.0	2.0	3.0	25.8	6.9	0.0	0.0	4.0	2.4
72	ICSR 90017	71.3	197.6	1.0	1.7	17.1	6.9	5.2	1.0	2.0	2.4
73	ICSV 93048	78.0	121.0	1.0	0.7	22.6	7.2	4.7	0.0	2.0	2.4
74	ICSV 95022	72.3	124.7	1.0	1.7	28.0	11.7	4.1	0.0	3.0	2.4
75	CHITICHI	65.1	137.3	2.0	4.3	20.2	6.3	17.0	0.0	2.0	1.9
76	ICSB 9	71.2	112.7	1.0	3.4	25.9	7.1	15.2	0.0	3.0	1.9
77	ICSR 24006	79.1	146.8	1.0	2.3	27.9	7.1	9.6	0.0	3.0	1.8
78	TESO # 15-3	77.6	231.5	2.0	2.8	26.9	7.6	0.8	0.0	1.0	1.8
79	TESO # 11_2	74.5	161.3	2.0	3.0	30.9	7.9	9.7	0.0	1.0	1.8
80	ICSR 172	69.4	121.8	1.0	1.5	23.7	6.6	4.2	0.0	2.0	1.7
81	ICSB 91002	72.7	118.5	2.0	1.6	24.0	5.4	15.8	0.0	3.0	1.8
82	ICSB 276	69.5	147.1	1.0	1.5	28.6	7.4	17.1	0.0	2.0	1.7
83	IESB 2	72.4	91.2	2.0	0.3	23.4	9.0	2.1	0.0	2.0	1.7
84	ICSB 89003	73.5	111.1	1.0	2.3	26.3	6.8	15.0	0.0	2.0	1.7
85	IESV 23006DL	75.3	152.1	1.0	1.0	26.2	10.7	12.7	1.0	2.0	1.5
86	ICSB 683	70.9	92.2	1.0	4.9	24.9	12.8	8.4	1.0	4.0	1.3
87	BUSIA #28-1	80.7	167.8	2.0	1.1	13.7	8.7	4.4	0.0	3.0	1.5
88	NAKHADABO	74.6	214.0	2.0	1.5	16.5	12.1	2.0	0.0	2.0	1.0
89	ICSR 24001	74.4	133.7	1.0	1.2	26.6	9.3	6.5	0.0	3.0	1.4
90	SP 74276	73.5	106.8	1.0	1.2	19.1	4.6	14.5	0.0	3.0	2.0
91	ICSB 371	75.6	126.3	2.0	2.8	24.7	5.7	13.5	0.0	3.0	2.2
92	ICSR 24003	77.1	112.7	1.0	1.6	29.6	8.2	2.1	0.0	1.0	2..1
93	ICSB 77	70.2	129.7	1.0	1.4	28.1	8.5	11.3	1.0	2.0	2.1
94	ICSR 89001	77.5	119.1	1.0	1.5	29.0	7.7	2.1	0.0	3.0	2.1
95	SDSB 29	69.5	133.1	2.0	1.5	30.2	6.9	6.1	0.0	2.0	2.1
96	ICSR 92003	73.4	147.6	1.0	3.9	30.2	10.6	3.4	0.0	2.0	2.1
97	IESV189	73.3	103.5	1.0	3.3	18.9	5.9	11.9	1.0	1.0	2.1
98	SDSB 1	72.2	132.1	2.0	1.2	32.5	6.3	9.5	0.0	2.0	2.1
99	ICSR 43	73.5	143.9	1.0	1.7	24.6	9.1	8.5	0.0	3.0	2.0
100	SIAYA # 97-1	73.1	246.5	1.0	0.7	20.5	6.3	2.4	0.0	2.0	2.0
101	ICSR 24008	72.9	129.9	1.0	2.3	28.3	9.7	4.4	0.0	3.0	2.0
102	ICSB 376	70.7	151.7	2.0	3.7	25.4	6.6	9.4	0.0	3.0	2.0
103	SIAYA # 81-2	73.6	156.8	2.0	2.7	24.5	10.3	0.4	0.0	3.0	2.0
104	ICSB 687	73.0	144.6	1.0	5.3	24.3	7.9	14.6	0.0	3.0	2.0
105	ZSV 3	70.3	170.2	2.0	2.5	17.0	6.2	18.5	0.0	3.0	1.9
106	ICSR 165	69.1	169.8	1.0	1.2	23.7	8.9	3.7	0.0	2.0	1.9
107	SDSB 4	73.6	146.7	2.0	2.4	29.1	5.3	5.7	0.0	2.0	1.9
108	SIAYA # 27-3	72.4	155.2	2.0	1.8	20.6	6.9	3.1	0.0	4.0	1.4
109	SIAYA # 66-2	67.0	142.2	2.0	3.3	22.8	13.8	4.0	0.0	1.0	1.9
110	ICSR 24004	76.7	168.7	1.0	5.8	25.0	8.0	2.6	0.0	1.0	1.9
111	SIAYA # 50-3	77.3	141.8	2.0	2.8	23.4	8.0	4.9	0.0	3.0	1.9
112	SIAYA # 93-1	67.5	161.1	2.0	1.7	20.3	5.5	9.9	0.0	4.0	1.8
113	ICSB 293	72.0	135.6	1.0	3.3	27.5	6.1	19.7	0.0	2.0	1.8
114	TEGEMEO	74.0	141.6	1.0	1.8	21.1	9.1	2.2	0.0	3.0	1.8
115	ICSR 24009	71.4	135.2	1.0	4.3	27.1	10.0	2.4	0.0	3.0	1.8
116	ICSR 24007	79.5	115.9	1.0	1.9	24.6	6.2	4.6	0.0	3.0	1.7
117	ICSR89028	75.8	155.3	2.0	2.3	21.6	7.3	6.7	0.0	2.0	1.5
118	ICSV 95046	74.1	141.9	2.0	1.0	29.1	15.6	1.7	0.0	3.0	1.7
119	SIAYA # 42	75.5	125.1	1.0	2.9	28.5	8.7	4.7	0.0	4.0	1.2
120	*Macia* (check)	72.7	120.7	1.0	1.5	25.2	8.2	7.0	0.0	3.0	3.2
	Overal Mean	**73.1**	**147.1**	**1.0**	**2.0**	**24.7**	**8.2**	**8.4**	**0.0**	**3.0**	**1.9**
	CV%	**7.0**	**9.2**	**16.0**	**69.0**	**9.7**	**23.3**	**43.7**	**13.5**	**27.0**	**1.7**
	LSD	**72.6**	**176.9**	**2.0**	**3.1**	**18.5**	**7.8**	**20.6**	**0.0**	**2.0**	**4.6**

Appendix V. Mean performance of sorghum lines at Kiboko during 2011- 2012 growing seasons based on yield and some yield components

No	Entry	DAF	HT (cm)	PC	TL	PS	PE (cm)	PL (cm)	PW (cm)	AW	GC	Y (t/ha)
1	B2 DN 55	66	108.7	1	0	6.6	14.8	23.1	6.0	0	2	2.0
2	BTX 623	68	134.8	2	0	6.2	6.6	27.8	6.6	0	2	2.2
3	BUSIA # 17-3	75	223.4	2	1	4.7	6.4	14.8	7.3	0	3	1.8
4	BUSIA # 28-1	71	203.4	2	1	6.8	3.2	12.4	7.7	0	3	2.3
5	BUSIA # 38 (SABINA)	76	231.6	2	1	6.1	1.3	20.4	7.7	0	3	1.7
6	CHITICHI	54	161.1	2	0	5.9	13.3	22.2	6.2	0	2	2.1
7	CK60B	66	112.5	2	0	6.8	10.4	22.3	5.5	0	2	1.9
8	ICSB 11	66	124.1	1	0	6.5	8.1	26.4	5.6	0	2	2.1
9	ICSB 12	68	130.8	1	0	6.3	4.9	32.9	7	0	2	2.2
10	ICSB 15	68	116.5	1	0	6.9	5.1	30.7	6.2	0	2	2.3
11	ICSB 276	69	173.1	1	0	5.4	12.8	31.8	7.9	0	2	2.8
12	ICSB 293	71	154.3	1	0	6	10.6	29.6	6.3	0	2	1.7
13	ICSB 324	71	180.2	1	0	5.7	9.7	30.4	8.2	0	1	2.4
14	ICSB 376	68	166.7	2	0	6.3	7.2	26.2	5.9	0	3	1.7
15	ICSB 452	71	146.9	1	1	6	4.6	27.5	6.6	0	2	2.2
16	ICSB 469	73	142.9	1	1	6.3	3.3	28.2	7.3	0	2	2.2
17	ICSB 479	69	178.1	1	0	6.8	4.2	19	6.9	1	2	2.2
18	ICSB 592	71	169.7	1	0	6	3.5	31.3	7	0	2	2.5
19	ICSB 686	64	123.5	1	1	6.3	7.4	24.1	6.6	1	2	1.9
20	ICSB 687	66	139.2	1	1	5.2	4.7	25	7.2	0	2	2.3
21	ICSB 88001	73	150.7	1	1	5.6	2.1	29.2	6.8	0	2	2.3
22	ICSB 88006	71	113.8	1	0	6.3	10.6	30.3	5.9	0	2	2.1
23	ICSB 89003	67	120.7	1	0	6	9.4	28.4	5.9	0	2	1.7
24	ICSB 9	66	120.6	1	0	5.4	7.9	28.2	6.2	0	2	2.0
25	ICSB 90001	72	135.8	1	0	5.3	2	30.4	8.6	0	2	2.4
26	ICSB 91002	68	116.5	2	0	6.5	5.3	27.3	6	0	3	2.1
27	ICSR 24005	73	128.5	1	0	6.9	4.7	28	6.7	0	2	2.2
28	ICSR 24006	73	180.7	1	0	6.5	3.8	31	7.1	0	2	2.0
29	ICSR 24007	75	130.7	1	0	6.8	3.6	26.7	6.5	0	2	2.4
30	ICSR 24009	72	155	2	0	6.3	2	27.7	7.2	0	2	2.5
31	ICSR 24010	69	215.8	1	0	5.9	6.4	22.4	8.1	0	2	2.3
32	ICSR 89001	74	128.5	1	0	7.2	2.7	30.2	7	0	2	2.6
33	ICSR 89028	73	141.3	1	0	6.6	3.9	30.3	8.5	0	2	2.7
34	ICSR 93001	70	148.3	1	0	6.8	3.6	27.1	7.3	0	2	2.5
35	ICSR 93034	70	209.4	1	0	6.5	3.2	26.6	8.2	0	2	2.8
36	ICSR153	70	153.4	1	0	6.2	3.9	30.1	7.1	0	2	2.1
37	ICSV 95022	69	131.8	1	0	5.6	1.7	30.9	9.1	0	3	2.6
38	ICSV 95023	63	145.9	1	0	5.7	6.4	25.3	6	0	3	1.6
39	ICSV 95046	69	143.9	2	0	4.4	1.9	30.6	10	0	3	1.9
40	IESB 2	69	111.8	2	0	5.4	0.6	26.4	7.6	0	2	1.7
41	IESV 20008 DL	70	194.8	1	0	6.6	4.8	23.6	8.1	0	2	2.2
42	IESV 23007 DL	68	168.3	1	0	6	6.7	26.9	7.6	0	3	2.3
43	IESV 23010 DL	63	153.7	1	0	5.7	5.3	24	7.5	0	3	2.4
44	IESV 23011 DL	69	185.9	2	0	4.9	7.4	31.1	8.8	1	2	2.6
45	IESV 23012 DL	68	144.1	2	0	5	5.7	30	7.8	1	2	2.5
46	IESV 23014 DL	71	122.7	2	0	4.7	1.9	32.5	8.8	1	3	2.3
47	IESV 23019 DL	70	173.5	2	0	5.3	1.7	32.4	8.4	1	3	2.4
48	IESV 91131 DL	70	122.4	1	0	6.8	1.4	26.5	7.6	0	2	2.5
49	IESV 92170 DL	66	174.7	2	0	4.9	11.3	27.3	7.3	0	3	2.1
50	IESV 94104 DL	66	151.2	1	0	6.3	3.8	23.9	7.5	0	3	2.6
51	IS 11167	75	303	2	0	7.7	10.4	15.1	7.2	1	3	2.0
52	IS 8884	70	208.1	2	0	7.8	4	10.7	5.9	0	3	2.3
53	KARIMTAMA1	68	168.6	1	0	6.6	4	24.7	7.9	0	2	2.7
54	MAKUENI LOCAL	67	232.6	2	3	4.1	7.2	21.4	9.2	0	3	2.2
55	MB 6	64	108.6	1	1	6.9	12.9	23.5	5.2	0	2	1.4
56	NAKHADABO	71	226	2	1	6.5	2.8	14.6	8.9	0	2	2.3
57	S 35	63	161.7	1	1	6.2	4.9	22.7	7.2	0	2	2.2
58	SERENA	67	148.2	2	1	6.3	0.7	26.2	7.2	0	3	1.9
59	SIAYA # 27-3	70	158.7	2	3	7.5	1.5	21.6	6.5	0	3	2.4
60	SIAYA # 42	70	168.8	2	2	7.6	2.5	19.3	6.2	0	3	2.5
61	SIAYA # 46-2	71	178.2	2	3	7.6	0.8	22.5	6.3	0	3	2.5
62	SIAYA # 50-3	68	163.4	2	1	7.1	1.1	23.4	6.7	0	3	2.5
63	SIAYA # 81-2	69	172.8	2	1	6.6	1.6	24.6	6.9	0	3	2.2
64	SIAYA # 93-1	68	185.1	2	1	7.5	2.4	23.7	6.9	0	3	2.4
65	SIAYA # 97-1	75	270.7	1	1	7.5	7.2	16.7	6.2	0	2	3.0
66	SP 74268	68	198.9	2	1	5	14.4	32.7	7.3	0	3	2.4
67	SP 74278	69	151.9	1	0	6.6	6.9	26.6	7	0	3	2.3
68	SP 74279	69	149	1	0	6.6	5.8	26.5	7	0	2	2.1
69	SP 74280	68	144.1	1	0	6.6	8.7	20.7	6.4	0	3	1.5
70	TEGEMEO	69	151.8	1	0	6.3	2.6	22.1	7.7	0	2	2.2
71	TESO # 17-2 (ETOROIT)	75	232.9	2	3	5.4	5.1	23.1	6.5	0	3	2.1
72	WAGITA	72	226.5	2	1	6	3.9	19.1	8.8	0	3	1.8
73	ZSV 3	63	178.1	2	1	7.2	9.3	18.5	6.5	0	2	1.7
74	*MACIA* (Check)	68	125.1	1	0	6.6	4.3	25.5	7.1	0	2	2.0
	GM	69	162.28	1.41	0.34	6.23	5.44	25.36	7.16	0.09	2.27	2.2
	SEM:	0.85	5.82	0.1	0.17	0.3	1.19	0.9	0.44	0.05	0.22	0.3
	LSD (0.05)	2.37	16.18	0.28	0.48	0.83	3.31	2.51	1.22	0.14	0.61	0.2
	CV	2.91	8.88	18.15	27.8	12.49	30.24	8.91	16.78	39.3	25.15	20.3

Appendix VI. Mean pperformance of sorghum lines at Miwaleni during 2011-2012 growing seasons

No	Entry	DAF	HT (cm)	PC	TL	PL (cm)	PW (cm)	PE (cm)	AW	GC	Y (t/ha)
1	B2 DN55	66	124.4	2	0	27.1	7.4	12	0	1	2.2
2	BTX 623	67	120.1	2	1	27.7	6.6	3.5	0	2	3.0
3	BUSIA #28-1	74	220.6	2	0	13.9	7.8	6.3	0	3	2.2
4	BUSIA #38 (SABINA)	76	254.1	2	1	17.6	7.8	3.5	0	3	2.4
5	BUSIA# 17-3	71	203	2	2	22.8	8.8	3.3	0	1	2.5
6	CHITICHI	54	114.8	2	0	22.3	4	6.8	0	1	2.4
7	CK 60B	67	100.6	2	2	23.6	6.7	7	0	5	2.2
8	ICSB 11	66	122.5	1	1	28.9	7	5.1	0	1	1.8
9	ICSB 12	69	127.8	1	0	32.4	6.7	4.2	0	2	2.1
10	ICSB 15	69	128.6	1	1	32.7	7.5	7.9	0	1	2.8
11	ICSB 276	72	161.9	1	0	30.7	6.9	15.9	0	1	2.4
12	ICSB 293	69	159.8	1	1	30.2	7.4	16.5	0	1	1.8
13	ICSB 324	68	172	1	1	27.5	6.4	12.6	0	1	2.2
14	ICSB 366	62	145.1	1	0	24.7	6.6	10.1	0	3	1.8
15	ICSB 371	65	155.9	2	1	27.1	5.9	13.8	0	3	1.9
16	ICSB 376	65	153.1	2	0	27.4	6.7	5.3	0	3	2.1
17	ICSB 44	70	122.2	1	0	24.6	6.7	5.4	0	1	2.3
18	ICSB 452	74	159.9	1	0	29.2	7.9	4.1	0	1	1.9
19	ICSB 469	72	147.7	1	0	27.5	7.3	3.6	0	1	1.7
20	ICSB 479	74	207.8	1	0	33.8	5.5	5.3	0	1	2.3
21	ICSB 592	69	158.5	1	0	32.6	7.2	3.9	0	1	2.1
22	ICSB 6	69	119.9	1	0	28.4	6.5	5.3	0	2	1.9
23	ICSB 654	66	145.2	1	1	26.1	8.5	10.9	0	3	2.3
24	ICSB 683	64	118.4	1	0	24.8	6.6	4.7	1	2	3.7
25	ICSB 686	66	141	1	0	26.5	8.3	5.6	1	1	2.2
26	ICSB 687	68	141.9	1	1	22.2	6.8	5.8	0	1	2.1
27	ICSB 73	72	164	1	0	24	7.5	4.6	0	1	2.5
28	ICSB 77	70	162.7	1	1	27.2	6.9	8.7	1	1	2.1
29	ICSB 88001	68	144.6	1	0	32	6.8	4	0	1	2.4
30	ICSB 88006	67	114	1	0	30.3	6.5	14	0	2	2.5
31	ICSB 89003	65	123.5	1	0	29.3	6.5	12.8	0	1	1.9
32	ICSB 9	65	119.7	1	0	28.5	7	7.8	0	1	2.5
33	ICSB 90001	68	130.2	1	0	34.8	7.7	1.5	0	1	2.4
34	ICSB 91002	66	120.1	2	0	27.5	7.8	3.1	0	3	2.3
35	ICSR 108	70	137.4	1	1	27.8	8.1	3.7	0	2	2.2
36	ICSR 160	73	193.1	1	1	25	7.6	4.2	0	2	2.6
37	ICSR 162	70	189.7	1	1	26.5	7.2	4	0	2	2.7
38	ICSR 165	67	170.3	1	0	25.7	7.8	1	0	1	1.9
39	ICSR 172	72	138.8	1	1	26.3	7.2	3.5	0	1	2.2
40	ICSR 196	77	153.5	1	0	26.1	7.5	3.3	0	1	2.3
41	ICSR 24001	73	138.5	1	0	25.9	7.9	0.4	0	1	1.7
42	ICSR 24003	72	148.1	1	0	30.3	8.1	3	0	1	1.8
43	ICSR 24004	72	160.6	1	1	31.6	9	0.5	0	1	2.8
44	ICSR 24005	72	133	1	0	30.7	6.9	2.9	0	1	2.5
45	ICSR 24006	72	167.3	1	1	30.7	6.6	4.9	0	1	1.9
46	ICSR 24007	68	139.6	1	1	27.8	7.4	3.4	0	1	2.4
47	ICSR 24008	75	146.7	1	1	27.8	7.8	2.8	0	2	2.3
48	ICSR 24009	70	155.4	1	1	27.6	7.8	2	0	2	2.3
49	ICSR 24010	70	170.3	1	0	21.9	6.6	2.6	0	1	1.7
50	ICSR 37	67	120.9	1	0	24.9	7.7	-0.1	0	2	1.9
51	ICSR 38	68	145.8	1	1	30.1	8.2	1.5	0	2	2.1
52	ICSR 43	70	151.1	1	1	32.1	7.6	2.9	0	2	1.8
53	ICSR 56	69	148.8	1	1	26.9	7.4	4.7	0	2	1.8
54	ICSR 89001	72	152.8	1	0	36.3	9.5	0.3	0	1	2.0
55	ICSR 89028	65	167.8	1	0	38.3	10	0.3	0	1	1.9
56	ICSR 89058	72	159	1	0	31.2	7.8	1.9	0	2	2.6
57	ICSR 89059	75	143.9	1	0	27.6	7.6	1	0	2	3.5
58	ICSR 89068	68	174.1	1	0	24.3	7.2	2.5	0	2	3.6
59	ICSR 90017	75	222.2	1	0	22.2	6.9	1.9	1	2	2.3
	Overal Mean	**68**	**158.9**	**1**	**0.5**	**26.5**	**7.5**	**5**	**0**	**2**	2.0
	CV%	**7.1**	**18.4**	**24**	**141**	**14.7**	**25.7**	**37.1**	**181**	**48**	28.0
	LSD	**59.6**	**196.2**	**2**	**0.8**	**21.4**	**5.5**	**9.3**	**0**	**3**	4.3

Appendix VI continues

No	Entry	DAF	HT (cm)	PC	TL	PL (cm)	PW (cm)	PE (cm)	AW	GC	Y (t/ha)
60	ICSR 92003	72	155.1	1	1	26.7	7.4	3.9	0	2	1.8
61	ICSR 93001	70	164.9	1	1	25.4	7.9	5	0	2	1.7
62	ICSR 93034	66	196	1	0	26.3	7.6	2.5	0	1	3.0
63	ICSR 153	73	158.8	1	0	26.5	7	0.3	0	1	2.0
64	ICSV 95023	65	151.8	2	0	31.3	11.8	2.5	0	3	2.5
65	ICSV 95046	67	152.2	1	0	30	8.1	1	0	2	2.2
66	IESV 189	71	171	1	0	24.1	8.1	4	0	2	2.35
67	ICSV 574	68	193.2	1	0	24.8	7.8	4.5	0	2	2.35
68	ICSV 93048	73	142.8	1	1	20.9	7.6	-1	0	4	1.85
69	ICSV 95022	68	127.6	1	1	35	8.4	-0.7	0	3	1.75
70	IESB 2	69	185.9	2	0	27.1	10.4	0.5	0	2	2.4
71	IESV 23005 DL	64	171.6	1	0	26.6	9.7	4.1	0	3	2.75
72	IESV 23006DL	66	177.1	1	1	27.9	7.8	6.2	0	3	2.05
73	IESV 23007 DL	65	164.1	1	0	26.9	8.3	3.7	0	3	2.8
74	IESV 23008 DL	64	168.5	1	1	25.9	8.8	2	0	3	1.9
75	IESV 23010 DL	65	166.1	1	1	27.5	9.5	3.5	0	3	2.75
76	IESV 23011 DL	69	179.1	2	0	29.6	8.2	8.1	1	3	2.75
77	IESV 23012 DL	65	132.2	2	0	33.2	6.8	2.2	1	3	1.85
78	IESV 23013 DL	67	170.6	2	1	32.8	10.9	5.3	1	3	2.4
79	IESV 23014 DL	65	122.6	2	1	34.8	9	1.6	1	3	2.45
80	IESV 23018 DL	74	191.1	2	0	35.1	10.9	0.2	1	4	2.1
81	IESV 23019 DL	68	178.1	2	1	31.2	7.6	4.4	1	3	2.1
82	IESV 91104 DL	61	185.9	1	1	21.7	8.2	5.4	0	2	3.45
83	IESV 91131 DL	67	129.3	1	1	27.7	8.4	5.3	0	2	3
84	IESV 92170 DL	70	246.9	2	1	23.9	7.4	14.5	0	4	2
85	IS 11167	79	209.5	2	0	11.4	5.8	9.1	0	3	1.9
86	IS 8884	68	186.4	1	1	14.6	6.4	3.4	0	3	2.05
87	KARI MTAMA 1	63	166.3	1	1	22	8.3	2.2	0	2	3.5
88	*MACIA*	66	129.6	1	1	24.1	7.7	3.9	0	2	1.9
89	MAKUENI LOCAL	60	194.3	2	0	26.6	6.5	13.7	0	3	2.9
90	MB 6	63	114	1	1	24	5.8	9.7	0	2	2.25
91	NAKHADABO	64	209.9	1	0	19	7	3.3	0	2	1.85
92	IESV189	66	109.5	2	1	24.5	8	4.5	0	2	1.65
93	S 35	65	156.3	1	0	26.1	6.6	3.3	0	2	2.2
94	SDSB 1	69	133.8	2	0	34.3	6.8	1.4	0	2	2.1
95	SDSB 29	72	141.2	2	0	32.8	6.4	1.6	0	2	3.4
96	SDSB 4	69	139.5	2	0	32.9	7.1	1.8	0	2	1.85
97	TESO # 17 (ETOROIT)	71	121.9	2	1	25.3	6.3	16.7	0	4	1.85
98	SIAYA # 27-3	67	200.7	1	2	22.5	7.5	7.6	0	2	1.55
99	SERENA	67	156.1	2	1	26.7	7.2	0.8	0	3	2.15
100	SIAYA # 27-3	72	170.6	2	1	20.6	6	1.1	0	3	1.95
101	SIAYA # 42	70	171.9	2	0	22.7	6.7	1.4	0	3	3.35
102	SIAYA # 46-2	68	173.4	2	0	23.7	6.8	0.9	0	3	2
103	SIAYA # 50-3	71	173.2	2	0	23.5	9.7	0.4	0	3	2.85
104	SIAYA # 78	72	225.8	2	0	23.3	7.4	3.4	0	4	2.25
105	SIAYA # 81-2	66	172.9	2	0	25.2	6.5	0.1	0	3	2.15
106	SIAYA # 93-1	71	250.5	2	1	22.6	6.4	4.8	0	2	1.95
107	SIAYA # 97-1	70	253.6	2	0	26.8	7.1	9.9	0	2	1.75
108	SIAYA #66-2 (GOPARI)	68	112.5	2	5	18.8	7.5	-0.8	0	1	2.05
109	SP 74268	71	196	1	0	31.4	7.6	11.1	0	3	2.5
110	SP 74276	66	136.7	1	0	26.3	6.7	3.2	0	3	3.25
111	SP 74277	66	141.4	1	0	26.6	7.9	5.9	0	3	1.8
112	SP 74278	73	155.8	1	1	26.4	7.4	5.3	0	3	2.35
113	SP 74279	66	153.3	1	0	25.6	7.1	3.8	0	3	1.75
114	SP 74280	70	136.8	2	0	24.4	6.1	8.8	0	3	1.65
115	SPL 9B	70	134.6	1	0	25.7	7.8	7.1	1	2	2.05
116	TEGEMEO	65	138.1	1	2	19.6	7.4	5.2	0	2	2.3
117	TESO # 11_2	71	230.9	2	1	29.8	6.1	4.8	0	2	1.85
118	TESO # 15-3	76	245	2	2	28	6.7	1.7	0	2	2.75
119	TESO # 17-2	75	242.9	2	2	23.7	6.8	13.4	0	4	2.25
120	WAGITA	67	181.4	2	1	21.6	8.6	6.3	0	3	2.1
121	ZSV 3	61	183.8	2	1	21	6.7	9.3	0	3	2.1
	Overal Mean	**68**	**158.9**	**1**	**0.5**	**26.5**	**7.5**	**5**	**0**	**2**	2.0
	CV%	**7.1**	**18.4**	**24**	**141**	**14.7**	**25.7**	**37.1**	**181**	**48**	28.0
	LSD	**59.6**	**196.2**	**2**	**0.8**	**21.4**	**5.5**	**9.3**	**0**	**3**	4.3

Appendix VII. Means of experimental hybrids for Days to flowering, yield per panicle and percent seed set during 2010 season

S/no	Hybrids	Days to flowering			Yield/panicle (g)			Seed set (%)			s/no	Hybrids	Days to Flowering			(g Yield/panicle) Seed set (%)					
		KB	MW	Av	KB	MW	Av	KB	MW	Av			KB	MW	Av	KB	MW	Av	KB	MW	Av
	ATX 623×ICSV 95022	76.0	62.0	69.0	170.9	114.3	142.6	100.0	100.0	100.0	170.0	SDSA 29×SIAYA #27-3	66.0	59.0	62.5	105.4	123.5	114.5	100.0	75.0	87.5
2	ATX 623× *MACIA*	76.0	60.0	68.0	95.3	137.4	116.4	100.0	100.0	100.0	171.0	SDSA 4×ICSR 160	72.0	60.0	66.0	82.8	105.9	94.3	95.0	80.0	87.5
3	ICSA 12 ×IESV 91104 DL	72.0	61.0	66.5	104.4	166.8	135.6	100.0	100.0	100.0	172.0	SDSA 4×ICSR 89058	75.0	58.0	66.5	86.1	80.0	83.1	100.0	75.0	87.5
4	ICSA 15× ICSR 93001	75.0	60.0	67.5	113.3	146.5	129.9	100.0	100.0	100.0	173.0	SPLA 9A×IESV 23019 DL	68.0	66.0	67.0	115.8	73.7	94.7	100.0	75.0	87.5
5	ICSA 371×*MACIA*	68.0	63.0	65.5	97.0	185.8	141.4	100.0	100.0	100.0	174.0	ICSA 44×TEGEMEO	67.0	61.0	64.0	94.3	83.3	88.8	98.0	75.0	86.5
6	ICSA 88006×ICSR 162	75.0	69.0	72.0	135.6	143.0	139.3	100.0	100.0	100.0	175.0	ICSA 88001×SIAYA#66-2	67.0	63.0	65.0	87.5	85.0	86.3	98.0	75.0	86.5
7	ICSA 88006× KARI MTAMA1	71.0	59.0	65.0	147.1	176.4	161.8	100.0	100.0	100.0	176.0	ICSA 88006×SIAYA#27-3	67.0	62.0	64.5	101.9	62.5	82.2	98.0	75.0	86.5
8	ICSA 9× ICSR 160	73.0	72.0	72.5	101.1	158.0	129.6	100.0	100.0	100.0	177.0	ICSA 89003×IESV 23011 DL	68.0	61.0	64.5	90.7	123.1	106.9	98.0	75.0	86.5
9	ICSA 90001× IESV 23013 DL	69.0	66.0	67.5	127.0	183.0	155.0	100.0	100.0	100.0	178.0	ICSA 12×S35	66.0	58.0	62.0	78.2	62.5	70.4	95.0	75.0	85.0
10	ICSA 91002× ICSR 24006	73.0	61.0	67.0	137.1	103.0	120.1	100.0	100.0	100.0	179.0	ICSA 293×ICSR 89001	64.0	61.0	62.5	108.4	83.3	95.9	90.0	80.0	85.0
11	SDSA 1×BUSIA#28-1	72.0	63.0	67.5	117.6	123.0	120.3	100.0	100.0	100.0	180.0	ICSA 376×IESV 23007 DL	65.0	62.0	63.5	104.2	80.0	92.1	90.0	80.0	85.0
12	SDSA 1×SIAYA #93-1	70.0	63.0	66.5	134.4	154.7	144.6	100.0	100.0	100.0	181.0	ICSA 687×IESV 23008 DL	67.0	58.0	62.5	105.5	130.0	117.8	95.0	75.0	85.0
13	SDSA 29 ×ICSR 43	73.0	63.0	68.0	124.7	128.0	126.4	100.0	100.0	100.0	182.0	ICSA 687×IESV 23013 DL	67.0	60.0	63.5	91.2	108.3	99.8	90.0	80.0	85.0
14	SDSA 29×ICSR 93034	68.0	59.0	63.5	145.0	113.0	129.0	100.0	100.0	100.0	183.0	ICSA 687×MR#22 X IS 8613/2/3-1-3	67.0	58.0	62.5	84.2	110.0	97.1	90.0	80.0	85.0
15	SDSA 29×IESV 91104 DL	72.0	60.0	66.0	129.9	108.0	119.0	100.0	100.0	100.0	184.0	ICSA 77×*MACIA*	69.0	68.0	68.5	110.1	150.0	130.0	80.0	90.0	85.0
16	SDSA 4×IESV 23019 DL	67.0	59.0	63.0	97.8	113.0	105.4	100.0	100.0	100.0	185.0	IESA2×ICSR 160	70.0	59.0	64.5	78.2	127.3	102.7	100.0	70.0	85.0
17	ICSA 12×ICSR 93001	72.0	60.0	66.0	104.5	108.0	106.3	98.0	100.0	99.0	186.0	SDSA 4×ICSR 89028	76.0	60.0	68.0	115.2	180.0	147.6	95.0	75.0	85.0
18	ICSA 12×KARI MTAMA 1	71.0	57.0	64.0	102.1	83.0	92.6	98.0	100.0	99.0	187.0	SPLA 9A×ICSR 92003	76.0	66.0	71.0	119.0	143.8	131.4	95.0	75.0	85.0
19	ICSA 12×SIAYA #46-2	69.0	62.0	65.5	107.7	158.0	132.9	98.0	100.0	99.0	188.0	ICSA 371×SIAYA#81-2	66.0	61.0	63.5	81.1	122.2	101.6	95.0	70.0	82.5
20	ICSA 15×ICSR 160	75.0	61.0	68.0	126.6	135.8	131.2	98.0	100.0	99.0	189.0	ICSA 687×ICSR 162	65.0	69.0	67.0	85.9	109.5	97.7	90.0	75.0	82.5
21	ICSA 15×ICSR 162	75.0	61.0	68.0	102.6	108.0	105.3	98.0	100.0	99.0	190.0	ICSA 9×MAKUENI LOCAL	65.0	70.0	67.5	97.3	150.0	123.6	95.0	70.0	82.5
22	ICSA 15×IESV 91104 DL	70.0	61.0	65.5	92.3	85.8	89.1	98.0	100.0	99.0	191.0	SDSA 4×IESV 23012 DL	67.0	62.0	64.5	91.5	33.3	62.4	95.0	70.0	82.5
23	ICSA 15×TEGEMEO	68.0	62.0	65.0	110.1	108.0	109.1	98.0	100.0	99.0	192.0	ICSA 6×ICSR 172	70.0	63.0	66.5	79.7	45.0	62.4	80.0	80.0	80.0
24	ICSA 293×ICSR 24009	72.0	69.0	70.5	133.8	86.9	110.4	98.0	100.0	99.0	193.0	ICSA 88001×IESV 91131 DL	69.0	58.0	63.5	110.0	122.2	116.1	90.0	70.0	80.0
25	ICSA 371× MAKUENI LOCAL	67.0	69.0	68.0	119.6	129.4	124.5	98.0	100.0	99.0	194.0	ICSA 88006×IESV 23011 DL	68.0	66.0	67.0	106.3	102.0	104.1	100.0	60.0	80.0
26	ICSA 44×ICSR 172	68.0	60.0	64.0	123.9	188.0	156.0	98.0	100.0	99.0	195.0	ICSA 89003×SP 74279	65.0	67.0	66.0	100.0	87.4	93.7	100.0	60.0	80.0
27	ICSA 44×IESV 91104 DL	67.0	67.0	67.0	145.2	126.2	135.7	98.0	100.0	99.0	196.0	SDSA 1×ICSR 24010	73.0	61.0	67.0	99.3	150.0	124.7	80.0	80.0	80.0
28	ICSA 44× MAKUENI LOCAL	73.0	59.0	66.0	137.6	66.8	102.2	98.0	100.0	99.0	197.0	SDSA 4×ICSR 89001	75.0	63.0	69.0	147.3	142.9	145.1	100.0	60.0	80.0
29	ICSA 88001× ICSR 93034	65.0	60.0	62.5	130.2	93.7	112.0	98.0	100.0	99.0	198.0	SDSA 4×ICSR 90017	81.0	58.0	69.5	121.3	100.0	110.6	90.0	70.0	80.0
30	ICSA 90001×IESV 23008 DL	70.0	62.0	66.0	138.2	102.7	120.5	100.0	98.0	99.0	199.0	ICSA 89003×SIAYA#27-3	69.0	61.0	65.0	132.0	260.0	196.0	98.0	60.0	79.0
31	IESA 2 ×BUSIA#28-1	72.0	59.0	65.5	104.5	79.4	92.0	100.0	98.0	99.0	200.0	ICSA 469×ICSV 574	71.0	69.0	70.0	39.6	78.9	59.3	60.0	95.0	77.5
32	SDSA 1×ICSR 43	73.0	61.0	67.0	124.6	76.8	100.7	100.0	98.0	99.0	201.0	SPL 9A×ICSR 37	75.0	62.0	68.5	118.9	90.0	104.4	95.0	60.0	77.5
33	SDSA 1×ICSR 92003	76.0	60.0	68.0	117.1	83.0	100.1	100.0	98.0	99.0	202.0	SPLA 9A×ICSR 162	77.0	64.0	70.5	123.8	130.8	127.3	95.0	60.0	77.5
34	SDSA 1×IESV 91104 DL	71.0	64.0	67.5	125.3	173.0	149.2	100.0	98.0	99.0	203.0	ICSA 73×ICSR 24008	78.0	70.0	74.0	91.6	71.4	81.5	50.0	100.0	75.0
35	SDSA 1×IESV 91131 DL	70.0	64.0	67.0	154.4	196.9	175.7	100.0	98.0	99.0	204.0	ICSA 276×ICSR 89059	70.0	71.0	70.5	98.6	105.6	102.1	50.0	95.0	72.5

Note: KB = Kiboko; MW = Miwaleni; Av = Average

Appendix VII continues

S/no	Hybrids	Days to 50% flowering			Yield/panicle (g)			Seed set (%)			s/no	Hybrids	Days to 50% flowering			Yield/panicle (g)			Seed set (%)		
		KB	MW	Av	KB	MW	Av	KB	MW	Av			KB	MW	Av	KB	MW	Av	KB	MW	Av
36	SDSA 29×ICSR 38	73.0	63.0	68.0	101.5	63.0	82.3	100.0	98.0	99.0	205.0	ICSA 9×ICSR 24010	70.0	61.0	65.5	157.3	76.9	117.1	95.0	50.0	72.5
37	SDSA 4×ICSR 24010	74.0	61.0	67.5	139.2	89.0	114.1	100.0	98.0	99.0	206.0	ICSA 376×SP 74279	66.0	63.0	64.5	90.0	107.7	98.8	90.0	50.0	70.0
38	SDSA 4×ICSR 92003	76.0	58.0	67.0	107.8	78.0	92.9	100.0	98.0	99.0	207.0	ICSA 687×KARI MTAMA 1	65.0	65.0	65.0	96.1	94.1	95.1	90.0	50.0	70.0
39	ICSA 90001×ICSR 89028	74.0	62.0	68.0	115.4	108.0	111.7	100.0	97.0	98.5	208.0	SDSA 29×ICSR 24010	76.0	66.0	71.0	111.7	67.0	89.4	50.0	90.0	70.0
40	ICSA 12×ICSR 162	73.0	58.0	65.5	114.6	145.5	130.1	98.0	98.0	98.0	209.0	ICSA 479×SP 74279	74.0	67.0	70.5	130.9	125.0	127.9	90.0	40.0	65.0
41	ICSA 12×SIAYA #42	70.0	61.0	65.5	125.7	117.5	121.6	98.0	98.0	98.0	210.0	ICSA 6×*MACIA*	72.0	59.0	65.5	163.5	121.1	142.3	98.0	30.0	64.0
42	ICSA 371×IESV 23006 DL	63.0	60.0	61.5	102.0	172.7	137.4	98.0	98.0	98.0	211.0	ICSA 88001×SP 74278	69.0	63.0	66.0	139.4	147.6	143.5	98.0	30.0	64.0
43	ICSA 371×IESV 23008 DL	67.0	63.0	65.0	112.1	263.6	187.9	98.0	98.0	98.0	212.0	ICSA 376×TEGEMEO	66.0	62.0	64.0	44.6	25.0	34.8	95.0	30.0	62.5
44	ICSA 9×ICSR 89058	71.0	67.0	69.0	107.9	108.0	108.0	98.0	98.0	98.0	213.0	ICSA 654×IESV 23007 DL	64.0	64.0	64.0	144.0	150.0	147.0	90.0	30.0	60.0
45	ATX 623×IESV 91104 DL	73.0	63.0	68.0	135.9	143.3	139.6	95.0	100.0	97.5	214.0	ICSA 73×TESO#15-3	75.0	60.0	67.5	155.5	112.6	134.1	90.0	30.0	60.0
46	CK 60A×ICSR 56	73.0	63.0	68.0	116.3	119.1	117.7	95.0	100.0	97.5	215.0	SPL 9A×ICSR 89058	77.0	63.0	70.0	129.4	83.3	106.4	95.0	25.0	60.0
47	CK 60A×IESV 91104 DL	67.0	63.0	65.0	97.5	92.2	94.9	95.0	100.0	97.5	216.0	SPL 9A×IESV 23010 DL	72.0	63.0	67.5	72.4	37.5	55.0	90.0	30.0	60.0
48	CK 60A×SP 74278	67.0	62.0	64.5	123.6	150.9	137.3	95.0	100.0	97.5	217.0	ICSA 77×ICSR 162	74.0	63.0	68.5	88.2	52.6	70.4	90.0	25.0	57.5
49	CK60A×IESV 23010 DL	65.0	61.0	63.0	114.7	96.9	105.8	95.0	100.0	97.5	218.0	IESA 2×ICSR 153	68.0	66.0	67.0	100.2	63.2	81.7	95.0	20.0	57.5
50	CK60A×SP 74279	69.0	60.0	64.5	116.0	115.1	115.6	95.0	100.0	97.5	219.0	ICSA 654×IESV 23005 DL	66.0	58.0	62.0	148.9	55.6	102.3	90.0	20.0	55.0
51	ICSA 12×IESV 23011 DL	69.0	60.0	64.5	136.8	108.0	122.4	95.0	100.0	97.5	220.0	ICSA 73×ICSR 160	78.0	63.0	70.5	100.9	68.8	84.8	50.0	60.0	55.0
52	ICSA 15×ICSR 172	73.0	61.0	67.0	111.5	88.0	99.8	95.0	100.0	97.5	221.0	ICSA 88006×ICSR 93001	75.0	59.0	67.0	91.7	83.3	87.5	100.0	2.0	51.0
53	ICSA 366×*MACIA*	67.0	52.0	59.5	133.2	148.0	140.6	95.0	100.0	97.5	222.0	ICSA 88006×ICSR 93034	70.0	60.0	65.0	87.8	70.0	78.9	100.0	92.0	80.0
54	ICSA 366×SIAYA #81-2	65.0	59.0	62.0	156.9	76.8	116.9	95.0	100.0	97.5	223.0	ICSA 88006×ICSV 574	75.0	60.0	67.5	106.2	113.3	109.8	100.0	2.0	51.0
55	ICSA 44×ZSV 3	62.0	62.0	62.0	104.5	116.3	110.4	95.0	100.0	97.5	224.0	ICSA 44×ICSV 95046	74.0	58.0	66.0	137.0	140.0	138.5	0.0	100.0	50.0
56	ICSA 88006×IESV 91131 DL	70.0	60.0	65.0	112.4	143.7	128.1	100.0	95.0	97.5	225.0	ICSA 44×SP 74276	67.0	61.0	64.0	124.7	87.5	106.1	0.0	100.0	50.0
57	ICSA 89003×ICSR 92003	76.0	63.0	69.5	171.8	208.0	189.9	100.0	95.0	97.5	226.0	ICSA 469× ICSR 24005	79.0	71.0	75.0	137.8	120.0	128.9	100.0	0.0	50.0
58	ICSA 89004×ICSR 43	73.0	61.0	67.0	178.0	172.3	175.2	95.0	100.0	97.5	227.0	ICSA 479×WAHI	72.0	64.0	68.0	172.4	146.7	159.6	100.0	0.0	50.0
59	ICSA 90001×ICSR 108	76.0	63.0	69.5	115.1	165.1	140.1	95.0	100.0	97.5	228.0	ICSA 6×ICSR 162	70.0	60.0	65.0	143.4	111.1	127.2	95.0	5.0	50.0
60	ICSA 90001×ICSR 43	76.0	63.0	69.5	82.5	108.0	95.3	100.0	95.0	97.5	229.0	ICSA 6×ICSR 93034	66.0	63.0	64.5	175.9	53.3	114.6	95.0	5.0	50.0
61	ICSA 90001×ICSR 92003	75.0	60.0	67.5	125.2	120.5	122.9	100.0	95.0	97.5	230.0	ICSA 88006×ICSR 89001	71.0	60.0	65.5	62.5	60.0	61.3	98.0	2.0	50.0
62	ICSA 91002×ICSR 24008	76.0	59.0	67.5	149.0	102.4	125.7	95.0	100.0	97.5	231.0	IESA2×IS 8884	69.0	59.0	64.0	121.3	133.3	127.3	40.0	60.0	50.0
63	ICSA 91002×ICSR 38	71.0	59.0	65.0	127.7	133.0	130.4	100.0	95.0	97.5	232.0	ICSA 44×IESV 23007 DL	68.0	69.0	68.5	119.0	100.0	109.5	98.0	0.0	49.0
64	IESA2×IESV 23014 DL	70.0	61.0	65.5	140.3	93.7	117.0	100.0	95.0	97.5	233.0	ICSA 452×ICSR 24005	82.0	59.0	70.5	135.8	100.0	117.9	0.0	98.0	49.0
65	SDSA 1×ICSR 24009	70.0	62.0	66.0	95.5	83.0	89.3	100.0	95.0	97.5	234.0	ICSA 376×SP 74276	66.0	62.0	64.0	132.9	107.1	120.0	0.0	95.0	47.5
66	SDSA 1×ICSR 93034	70.0	60.0	65.0	152.9	108.0	130.5	100.0	95.0	97.5	235.0	ICSA 6×IESV 23011 DL	66.0	66.0	66.0	136.3	107.7	122.0	95.0	0.0	47.5
67	SDSA 1×IESV 23018 DL	70.0	64.0	67.0	132.5	89.0	110.8	100.0	95.0	97.5	236.0	ICSA 687×TEGEMEO	68.0	69.0	68.5	148.4	87.5	118.0	90.0	5.0	47.5
68	SDSA 4×ICSR 38	73.0	63.0	68.0	129.4	83.0	106.2	100.0	95.0	97.5	237.0	ICSA 73× ICSV 95022	75.0	70.0	72.5	107.8	89.5	98.7	0.0	95.0	47.5
69	SDSA 4×ICSR 43	74.0	63.0	68.5	147.0	83.0	115.0	100.0	95.0	97.5	238.0	ICSA 469×SIAYA #66-2	73.0	63.0	68.0	112.3	114.3	113.3	90.0	3.0	46.5
70	ICSA 12×IESV 23019 DL	70.0	60.0	65.0	95.9	153.5	124.7	95.0	98.0	96.5	239.0	ICSA 293×ICSR 89059	64.0	58.0	61.0	122.8	150.0	136.4	50.0	40.0	45.0

Appendix VII continues

S/no	Hybrids	Days to 50% flowering			Yield/panicle (g)			Seed set (%)			s/no	Hybrids	Days to 50% Flowering			Yield/panicle (g)			Seed set %		
		KB	MW	Av	KB	MW	Av	KB	MW	Av			KB	MW	Av	KB	MW	Av	KB	MW	Av
71	ICSA 276×ICSR 24008	76.0	69.0	72.5	128.4	96.9	112.7	98.0	95.0	96.5	240.0	ICSA 654×IESV 23006 DL	64.0	63.0	63.5	106.6	108.3	107.5	80.0	10.0	45.0
72	ICSA 276×NAKHADABO	72.0	70.0	71.0	110.0	122.3	116.2	98.0	95.0	96.5	241.0	ICSA 654×IESV 23008 DL	64.0	60.0	62.0	104.9	85.7	95.3	80.0	10.0	45.0
73	ICSA 376×IESV 23013 DL	68.0	66.0	67.0	137.7	80.2	109.0	95.0	98.0	96.5	242.0	ICSA 683×IESV 23008 DL	66.0	62.0	64.0	99.4	133.3	116.4	0.0	90.0	45.0
74	ICSA 6×MAKUENI LOCAL	68.0	65.0	66.5	129.3	133.0	131.2	98.0	95.0	96.5	243.0	ICSA 686×ICSR 93034	65.0	60.0	62.5	110.0	93.3	101.7	50.0	40.0	45.0
75	ICSA 88001×*MACIA*	73.0	64.0	68.5	116.3	198.0	157.2	98.0	95.0	96.5	244.0	ICSA 73×BUSIA#38	77.0	69.0	73.0	112.6	95.2	103.9	0.0	90.0	45.0
76	ICSA 88006×SIAYA#97-1	74.0	62.0	68.0	106.6	101.3	104.0	95.0	98.0	96.5	245.0	SDSA1×HAKIKA	73.0	64.0	68.5	103.3	80.0	91.7	0.0	90.0	45.0
77	ICSA 9×ICSR 108	70.0	63.0	66.5	125.6	84.5	105.1	98.0	95.0	96.5	246.0	ICSA 654×IESV 23004 DL	72.0	58.0	65.0	93.9	118.8	106.3	0.0	85.0	42.0
78	ICSA 9×ICSR 56	69.0	61.0	65.0	138.6	83.0	110.8	95.0	98.0	96.5	247.0	ICSA 686×SP 74280	67.0	59.0	63.0	97.9	75.0	86.4	0.0	85.0	42.5
79	ICSA 9×ICSR 89001	69.0	66.0	67.5	123.9	91.3	107.6	95.0	98.0	96.5	248.0	ICSA 687×SP 74276	72.0	69.0	70.5	150.3	81.0	115.6	5.0	80.0	42.5
80	ICSA 90001×ICSR 89058	72.0	61.0	66.5	127.8	130.2	129.0	95.0	98.0	96.5	249.0	ICSA 6×ICSV 95046	77.0	70.0	73.5	130.7	63.2	97.0	0.0	80.0	40.0
81	MA 6×MAKUENI LOCAL	65.0	63.0	64.0	132.2	95.5	113.9	95.0	98.0	96.5	250.0	ICSA 687×ICSR 93034	67.0	61.0	64.0	115.5	100.0	107.8	80.0	0.0	40.0
82	SDSA 29×ICSR 89059	76.0	59.0	67.5	127.9	100.9	114.4	95.0	98.0	96.5	251.0	ICSA 90001×BUSIA#38	72.0	63.0	67.5	134.0	100.0	117.0	0.0	80.0	40.0
83	ATX 623×IESV 23012 DL	67.0	61.0	64.0	120.9	138.8	129.9	95.0	95.0	95.0	252.0	SDSA 29×ICSR 90017	82.0	62.0	72.0	160.6	200.0	180.3	30.0	50.0	40.0
84	ATX 623×KARI MTAMA 1	70.0	61.0	65.5	109.9	201.3	155.6	95.0	95.0	95.0	253.0	ICSA 687×*MACIA*	65.0	58.0	61.5	120.0	92.3	106.1	50.0	25.0	37.5
85	ATX 623×MAKUENI LOCAL	67.0	59.0	63.0	128.6	163.6	146.1	95.0	95.0	95.0	254.0	ICSA 73×ICSR 196	75.0	70.0	72.5	109.9	166.7	138.3	50.0	25.0	37.5
86	CK 60A×KARI MTAMA 1	66.0	57.0	61.5	142.9	46.5	94.7	95.0	95.0	95.0	255.0	ICSA 276×ICSR 90017	68.0	71.0	69.5	122.6	76.2	99.4	60.0	10.0	35.0
87	CK60A×ICSR 160	70.0	61.0	65.5	136.9	102.1	119.5	95.0	95.0	95.0	256.0	ICSA 686×MAKUENI LOCAL	65.0	63.0	64.0	102.2	90.0	96.1	50.0	15.0	32.5
88	ICSA 11×IESV 92170 DL	70.0	60.0	65.0	126.1	134.9	130.5	95.0	95.0	95.0	257.0	ICSA 73×ICSR 93001	76.0	70.0	73.0	103.8	109.1	106.4	0.0	60.0	30.0
89	ICSA 12×ICSR 172	70.0	60.0	65.0	141.4	146.5	144.0	95.0	95.0	95.0	258.0	ICSA 91002×ICSR 153	73.0	60.0	66.5	130.3	90.9	110.6	10.0	50.0	30.0
90	ICSA 366×KARI MTAMA 1	66.0	52.0	59.0	115.5	193.7	154.6	95.0	95.0	95.0	259.0	SPLA 9A×ICSR 93034	77.0	66.0	71.5	114.5	93.3	103.9	50.0	5.0	27.5
91	ICSA 371×IESV 23005 DL	62.0	61.0	61.5	129.7	102.7	116.2	95.0	95.0	95.0	260.0	ICSA 276×SP 74276	67.0	60.0	63.5	111.5	68.4	90.0	0.0	50.0	25.0
92	ICSA 376×ICSR 93001	70.0	61.0	65.5	114.0	138.8	126.4	95.0	95.0	95.0	261.0	ICSA 88001×ICSR 172	64.0	58.0	61.0	95.3	95.2	95.2	0.0	50.0	25.0
93	ICSA 687×IESV 23010 DL	66.0	59.0	62.5	121.7	145.5	133.6	95.0	95.0	95.0	262.0	IESA2×ICSR 24006	69.0	58.0	63.5	97.4	75.0	86.2	50.0	0.0	25.0
94	ICSA 88001×ICSR 160	72.0	60.0	66.0	178.9	136.6	157.8	100.0	90.0	95.0	263.0	ICSA 683×ICSR 162	73.0	64.0	68.5	135.0	200.0	167.5	10.0	35.0	22.5
95	ICSA 89003×ICSR 89058	75.0	63.0	69.0	127.7	128.0	127.9	100.0	90.0	95.0	264.0	ICSA 654×MAKUENI LOCAL	66.0	62.0	64.0	139.8	98.4	119.1	20.0	20.0	20.0
96	ICSA 89003× ICSR 93034	71.0	62.0	66.5	141.2	86.6	113.9	100.0	90.0	95.0	265.0	ICSA 73×IESV 91131 DL	70.0	70.0	70.0	117.7	128.6	123.1	0.0	40.0	20.0
97	ICSA 89004×IESV 23013 DL	71.0	62.0	66.5	137.4	141.3	139.4	95.0	95.0	95.0	266.0	ICSA 687×SP 74280	68.0	69.0	68.5	148.8	121.1	134.9	30.0	5.0	17.5
98	ICSA 90001 X ICSR 37	70.0	63.0	66.5	163.6	134.3	149.0	95.0	95.0	95.0	267.0	ICSA 73×ICSR 162	76.0	70.0	73.0	130.2	85.0	107.6	10.0	20.0	15.0
99	ICSA 90001×ICSR 89001	76.0	58.0	67.0	131.4	133.0	132.2	100.0	90.0	95.0	268.0	ICSA 293×ICSR 89028	63.0	58.0	60.5	148.1	80.0	114.0	5.0	20.0	12.5
100	IESA 2×ICSR 24008	70.0	59.0	64.5	122.4	97.5	110.0	100.0	90.0	95.0	269.0	ICSA 654×ICSR 37	66.0	58.0	62.0	122.1	112.5	117.3	5.0	20.0	12.5
101	IESA2×ICSR 24009	71.0	60.0	65.5	118.5	108.0	113.3	95.0	95.0	95.0	270.0	ICSA 654×ICSR 56	72.0	61.0	66.5	125.4	145.5	135.4	0.0	25.0	12.5
102	IESA2×ICSR 24010	70.0	60.0	65.0	144.4	83.0	113.7	100.0	90.0	95.0	271.0	ICSA 683×SIAYA #50-3	66.0	58.0	62.0	128.5	105.6	117.0	5.0	20.0	12.5
103	MA 6×S35	65.0	60.0	62.5	148.8	124.7	136.8	95.0	95.0	95.0	272.0	ICSA 88006×SP 74280	71.0	64.0	67.5	152.9	109.5	131.2	5.0	20.0	12.5
104	MA6×IESV 23010 DL	64.0	62.0	63.0	105.1	93.7	99.4	100.0	90.0	95.0	273.0	ICSA 479×*MACIA*	81.0	66.0	73.5	78.0	75.0	76.5	0.0	20.0	10.0
105	SDSA 1×ICSR 38	73.0	62.0	67.5	63.4	45.5	54.5	95.0	95.0	95.0	274.0	ICSA 686×IESV 23008 DL	65.0	60.0	62.5	136.3	175.0	155.6	20.0	0.0	10.0

Appendix VII continues

S/no	Hybrids	Days to 50% flowering			Yield/panicle (g)			Seed set (%)			s/no	Hybrids	Days to 50% flowering			Yield/panicle (g)			Seed set (%)		
		KB	MW	Av	KB	MW	Av	KB	MW	Av			KB	MW	Av	KB	MW	Av	KB	MW	Av
106	SDSA 1×ICSR 93001	74.0	62.0	68.0	76.6	55.4	66.0	100.0	90.0	95.0	275.0	ICSA 90001×SP 74280	69.0	62.0	65.5	118.6	109.1	113.9	0.0	20.0	10.0
107	SDSA 29×ICSR 37	74.0	62.0	68.0	113.5	126.2	119.9	95.0	95.0	95.0	276.0	ICSA 91002×ICSR 24001	64.0	60.0	62.0	94.8	100.0	97.4	0.0	20.0	10.0
108	SDSA 4×IESV 91104 DL	70.0	62.0	66.0	84.5	77.2	80.9	100.0	90.0	95.0	277.0	ICSA 683× SIAYA#42-3	74.0	58.0	66.0	69.6	88.9	79.2	0.0	15.0	7.5
109	ICSA 11×ICSR 172	72.0	60.0	66.0	60.5	68.0	64.3	98.0	90.0	94.0	278.0	ICSA 88001×ICSV 574	61.0	58.0	59.5	91.4	115.0	103.2	0.0	15.0	7.5
110	ICSA 11×IESV 91104 DL	70.0	58.0	64.0	68.3	65.1	66.7	98.0	90.0	94.0	279.0	ICSA 88006× ICSV 93048	59.0	60.0	59.5	152.9	125.0	139.0	0.0	15.0	7.5
111	ICSA 11×SP 74279	67.0	59.0	63.0	160.4	150.9	155.7	90.0	98.0	94.0	280.0	ICSA 452×ICSR 24007	81.0	61.0	71.0	134.4	111.1	122.8	10.0	0.0	5.0
112	ICSA 276×ICSR 162	70.0	69.0	69.5	97.5	74.7	86.1	98.0	90.0	94.0	281.0	ICSA 683×ICSR 172	72.0	69.0	70.5	126.3	71.8	99.0	5.0	5.0	5.0
113	ICSA 77×ICSR 108	71.0	60.0	65.5	58.0	79.4	68.7	98.0	90.0	94.0	282.0	ICSA 683×IESV 23010 DL	68.0	60.0	64.0	144.5	100.0	122.2	10.0	0.0	5.0
114	ICSA 88001×ICSR 108	69.0	66.0	67.5	61.1	108.0	84.6	98.0	90.0	94.0	283.0	ICSA 683×SIAYA #81-2	65.0	59.0	62.0	120.8	71.4	96.1	5.0	5.0	5.0
115	ICSA 89003×SIAYA#42-3	66.0	66.0	66.0	63.5	208.0	135.8	98.0	90.0	94.0	284.0	ICSA 77× SP 74280	66.0	68.0	67.0	124.2	100.0	112.1	0.0	10.0	5.0
116	ICSA 9×ICSV 93034	67.0	67.0	67.0	69.5	74.7	72.1	98.0	90.0	94.0	285.0	ICSA88001×ICSV 95046	76.0	61.0	68.5	117.0	66.7	91.8	5.0	0.0	2.5
117	ICSA 90001×HAKIKA	71.0	63.0	67.0	143.6	108.0	125.8	98.0	90.0	94.0	286.0	ICSA469×SP 74276	70.0	57.0	63.5	198.3	76.2	137.2	0.0	5.0	2.5
118	SDSA 1×ICSR 37	72.0	62.0	67.0	56.6	50.9	53.8	90.0	98.0	94.0	287.0	ICSA 44×SP 74277	71.0	63.0	67.0	129.2	64.3	96.7	5.0	0.0	2.5
119	ATX 623×IESV 23019 DL	68.0	62.0	65.0	54.3	43.7	49.0	90.0	95.0	92.5	288.0	ICSA 479×IESV 91131 DL	81.0	66.0	73.5	128.8	57.9	93.3	0.0	5.0	2.5
120	ATX 623×IESV 91131 DL	72.0	68.0	70.0	56.1	54.2	55.2	95.0	90.0	92.5	289.0	ICSA 479×SIAYA#66-2	82.0	66.0	74.0	106.7	28.6	67.6	0.0	5.0	2.5
121	ICSA 11×S35	65.0	58.0	61.5	52.6	35.8	44.2	95.0	90.0	92.5	290.0	ICSA 654×ICSR 38	72.0	58.0	65.0	138.4	42.1	90.3	5.0	0.0	2.5
122	ICSA 12×ICSR 160	74.0	60.0	67.0	55.5	36.6	46.1	90.0	95.0	92.5	291.0	ICSA 654× ICSR 172	70.0	63.0	66.5	105.0	64.7	84.9	0.0	5.0	2.5
123	ICSA 293×ICSR 24010	72.0	60.0	66.0	53.1	133.0	93.1	100.0	85.0	92.5	292.0	ICSA 683×SIAYA #27-3	65.0	61.0	63.0	106.6	72.2	89.4	5.0	0.0	2.5
124	ICSA 371×TESO#11-2	64.0	61.0	62.5	51.9	258.0	155.0	90.0	95.0	92.5	293.0	ICSA 686×ICSR 172	75.0	63.0	69.0	114.2	111.1	112.7	0.0	5.0	2.5
125	ICSA 654×ICSR 153	70.0	59.0	64.5	55.9	45.5	50.7	90.0	95.0	92.5	294.0	ICSA 73× ICSR 38	70.0	63.0	66.5	101.1	65.0	83.0	0.0	5.0	2.5
126	ICSA 687×IESV 23011 DL	70.0	61.0	65.5	50.1	68.0	59.1	90.0	95.0	92.5	295.0	ICSA 77×SP 74277	68.0	69.0	68.5	102.5	81.3	91.9	0.0	5.0	2.5
127	ICSA 77×ICSR 196	73.0	60.0	66.5	55.5	85.8	70.7	95.0	90.0	92.5	296.0	ICSA 88001×SP 74277	69.0	63.0	66.0	76.5	85.7	81.1	0.0	5.0	2.5
128	ICSA 89004×ICSR 89028	72.0	63.0	67.5	62.6	43.7	53.2	95.0	90.0	92.5	297.0	ICSA 88006×ICSR 24001	79.0	66.0	72.5	106.1	111.1	108.6	0.0	5.0	2.5
129	ICSA 91002× SIAYA#42	71.0	59.0	65.0	53.2	128.0	90.6	100.0	85.0	92.5	298.0	SPLA 9A×SIAYA #50-3	75.0	66.0	70.5	108.1	128.6	118.3	0.0	5.0	2.5
130	IESA 2×ICSR 24007	68.0	58.0	63.0	51.3	45.5	48.4	95.0	90.0	92.5	299.0	ICSA 12×SP 74276	68.0	59.0	63.5	76.7	126.7	101.7	0.0	2.0	1.0
131	SDSA 1×ICSR 160	75.0	63.0	69.0	55.3	34.7	45.0	90.0	95.0	92.5	300.0	ICSA 479× IESV 92170 DL	81.0	67.0	74.0	98.9	100.0	99.5	0.0	2.0	1.0
132	SDSA 4×ICSR 24009	71.0	61.0	66.0	101.3	31.1	66.2	100.0	85.0	92.5	301.0	A2DN55×AF 28	76.0	62.0	69.0	138.7	152.6	145.6	0.0	1.0	0.0
133	SPLA 9A×HAKIKA	78.0	59.0	68.5	123.8	108.0	115.9	95.0	90.0	92.5	302.0	ICSA 73× SP 74280	78.0	64.0	71.0	105.5	120.0	112.8	0.0	1.0	0.0
134	ICSA 11×ICSR 160	75.0	60.0	67.5	143.6	51.8	97.7	98.0	85.0	91.5	303.0	A2DN55×HAKIKA	72.0	59.0	65.5	116.5	131.3	123.9	0.0	0.0	0.0
135	ICSA 44×ICSR 162	71.0	60.0	65.5	135.2	113.0	124.1	98.0	85.0	91.5	304.0	A2DN55×IESV 23005 DL	68.0	60.0	64.0	132.0	100.0	116.0	0.0	0.0	0.0
136	ICSA 89003×SIAYA#46-2	67.0	63.0	65.0	140.9	83.0	112.0	98.0	85.0	91.5	305.0	A2DN55×SIAYA #81-2	70.0	62.0	66.0	112.2	170.6	141.4	0.0	0.0	0.0
137	ICSA 276×ICSR 93001	64.0	59.0	61.5	95.8	86.9	91.4	90.0	90.0	90.0	306.0	A2DN55×TESO#11-2	66.0	60.0	63.0	107.5	114.3	110.9	0.0	0.0	0.0
138	ICSA 366×IESV 91131 DL	68.0	59.0	63.5	120.8	108.0	114.4	95.0	85.0	90.0	307.0	ATX 623×SP 74280	70.0	63.0	66.5	140.1	70.6	105.3	0.0	0.0	0.0
139	ICSA 366×MAKUENI LOCAL	65.0	61.0	63.0	129.2	108.0	118.6	90.0	90.0	90.0	308.0	ICSA 11×ICSV 95046	75.0	58.0	66.5	118.8	125.0	121.9	0.0	0.0	0.0
140	IESA2×ICSR 24005	70.0	61.0	65.5	153.2	119.1	136.2	100.0	80.0	90.0	309.0	ICSA 77×ICSV 189	72.0	60.0	66.0	134.3	90.0	112.1	0.0	0.0	0.0

Appendix VII continues

S/no		Days to 50% flowering			Yield/panicle (g)			Seed set (%)			s/no	Hybrids	Days to 50% flowering			Yield/panicle (g)			Seed set (%)		
	Hybrids	KB	MW	Av	KB	MW	Av	KB	MW	Av			KB	MW	Av	KB	MW	Av	KB	MW	Av
141	MA 6×ZSV 3	59.0	65.0	62.0	155.1	174.7	164.9	90.0	90.0	90.0	310.0	ICSA 683×ICSV 95046	72.0	60.0	66.0	128.1	141.7	134.9	0.0	0.0	0.0
142	SDSA 29×ICSR 89068	70.0	63.0	66.5	145.0	108.0	126.5	95.0	85.0	90.0	311.0	ICSA 683×ICSV 189	73.0	61.0	67.0	104.1	126.3	115.2	0.0	0.0	0.0
143	SDSA 4×ICSR 89059	80.0	58.0	69.0	92.4	79.4	85.9	95.0	85.0	90.0	312.0	ICSA 73×SP 74276	68.0	60.0	64.0	103.6	105.6	104.6	0.0	0.0	0.0
144	SDSA 4×ICSR 93034	68.0	61.0	64.5	80.0	86.6	83.3	100.0	80.0	90.0	313.0	ICSA 452×ICSR 24006	83.0	59.0	71.0	131.9	123.8	127.8	0.0	0.0	0.0
145	CK 60A×ICSR 172	70.0	62.0	66.0	104.8	65.1	85.0	98.0	80.0	89.0	314.0	ICSA 452×ICSR 24009	81.0	60.0	70.5	111.3	100.0	105.7	0.0	0.0	0.0
146	ICSA 276×IESV 91104 DL	69.0	62.0	65.5	117.7	98.0	107.9	98.0	80.0	89.0	315.0	ICSA 452×WAGITA	84.0	63.0	73.5	111.2	105.3	108.2	0.0	0.0	0.0
147	ICSA 366×IESV 23006 DL	65.0	60.0	62.5	106.7	64.3	85.5	98.0	80.0	89.0	316.0	ICSA 469×ICSR 24003	87.0	69.0	78.0	119.1	100.0	109.5	0.0	0.0	0.0
148	ICSA 88001×ICSR 162	75.0	59.0	67.0	110.9	108.0	109.5	98.0	80.0	89.0	317.0	ICSA 469×ICSV 95022	87.0	69.0	78.0	108.2	110.5	109.4	0.0	0.0	0.0
149	ICSA 88001×ICSR 196	73.0	59.0	66.0	106.6	71.2	88.9	98.0	80.0	89.0	318.0	ICSA 469×IESV 23011 DL	88.0	69.0	78.5	153.0	138.1	145.6	0.0	0.0	0.0
150	ICSA 88001×SIAYA#27-3	67.0	66.0	66.5	103.2	64.3	83.8	98.0	80.0	89.0	319.0	ICSA 469× SP 74280	84.0	69.0	76.5	118.8	116.7	117.7	0.0	0.0	0.0
151	ICSA 88006×SIAYA#66-2	70.0	66.0	68.0	100.7	78.0	89.4	100.0	78.0	89.0	320.0	ICSA 469×NAKHADABO	84.0	69.0	76.5	119.1	116.7	117.9	0.0	0.0	0.0
152	ATX 623×ICSR 160	76.0	62.0	69.0	96.3	89.8	93.1	95.0	80.0	87.5	321.0	ICSA 469×WAGITA	82.0	63.0	72.5	131.6	90.0	110.8	0.0	0.0	0.0
153	ATX 623×IESV 23010 DL	68.0	61.0	64.5	122.9	115.1	119.0	95.0	80.0	87.5	322.0	ICSA 479×ICSR 196	81.0	66.0	73.5	117.1	85.0	101.1	0.0	0.0	0.0
154	ICSA 276×ICSR 92003	77.0	71.0	74.0	83.0	158.0	120.5	95.0	80.0	87.5	323.0	ICSA 479×ICSR 24001	80.0	64.0	72.0	104.3	88.0	96.1	0.0	0.0	0.0
155	ICSA 293×ICSR 24007	74.0	69.0	71.5	110.7	119.1	114.9	95.0	80.0	87.5	324.0	ICSA 479×ICSR 24004	82.0	66.0	74.0	95.8	80.0	87.9	0.0	0.0	0.0
156	ICSA 376×SP 74278	68.0	62.0	65.0	103.7	85.8	94.8	95.0	80.0	87.5	325.0	ICSA 479×ICSV 95022	81.0	66.0	73.5	167.8	84.6	126.2	0.0	0.0	0.0
157	ICSA 6×MR#22 X IS 8613/2/3-1-3	69.0	66.0	67.5	105.4	158.0	131.7	95.0	80.0	87.5	326.0	ICSA 479× IESV 23014 DL	81.0	64.0	72.5	128.3	100.0	114.1	0.0	0.0	0.0
158	ICSA 687×ICSV 95022	66.0	59.0	62.5	98.8	34.7	66.8	95.0	80.0	87.5	327.0	ICSA 479×IESV 23018 DL	80.0	64.0	72.0	122.8	55.0	88.9	0.0	0.0	0.0
159	ICSA 687×MAKUENI LOCAL	68.0	62.0	65.0	68.9	58.0	63.5	95.0	80.0	87.5	328.0	ICSA 479×KARI MTAMA 1	82.0	66.0	74.0	152.4	73.7	113.0	0.0	0.0	0.0
160	ICSA 687×SIAYA#27-3	67.0	67.0	67.0	71.7	78.0	74.9	90.0	85.0	87.5	329.0	ICSA 479×MAKUENI LOCAL	81.0	65.0	73.0	123.6	60.0	91.8	0.0	0.0	0.0
161	ICSA 77×SIAYA#97-1	82.0	64.0	73.0	83.6	124.7	104.2	95.0	80.0	87.5	330.0	ICSA 479×NAKHADABO	82.0	66.0	74.0	129.3	55.6	92.4	0.0	0.0	0.0
162	ICSA 88001×KARI MTAMA 1	67.0	59.0	63.0	73.6	120.5	97.1	95.0	80.0	87.5	331.0	ICSA 683×IESV 23011 DL	67.0	58.0	62.5	135.2	47.1	91.1	0.0	0.0	0.0
163	ICSA 89003×KARI MTAMA 1	71.0	60.0	65.5	80.5	93.7	87.1	95.0	80.0	87.5	332.0	ICSA 683×IESV 23012 DL	67.0	59.0	63.0	125.1	65.0	95.0	0.0	0.0	0.0
164	ICSA 9×ICSR 38	74.0	63.0	68.5	65.1	108.0	86.6	95.0	80.0	87.5	333.0	ICSA 686×ICSV 189	70.0	59.0	64.5	117.7	70.6	94.1	0.0	0.0	0.0
165	ICSA 9×ICSR 89028	71.0	66.0	68.5	69.6	95.5	82.6	95.0	80.0	87.5	334.0	ICSA 686×TEGEMEO	68.0	59.0	63.5	145.6	72.2	108.9	6.0	0.0	0.0
166	ICSA 90001×ICSR 24008	76.0	63.0	69.5	78.9	78.0	78.5	80.0	95.0	87.5	335.0	ICSA 77×SP 74276	69.0	64.0	66.5	184.8	88.9	136.8	0.0	0.0	0.0
167	IESA2×ICSR 24004	68.0	60.0	64.0	107.8	78.0	92.9	95.0	80.0	87.5	336.0	ICSA 89003×SP 74280	71.0	67.0	69.0	154.9	94.4	124.7	0.0	0.0	0.0
168	MA 6×ICSV 95023	64.0	59.0	61.5	93.5	115.1	104.3	95.0	80.0	87.5	337.0	ICSA 9×ICSR 24001	75.0	61.0	68.0	97.0	119.8	108.4	0.0	0.0	0.0
169	SDSA 29×ICSR 160	80.0	63.0	71.5	85.3	158.0	121.7	95.0	80.0	87.5											

Note: KB = Kiboko; MW = Miwaleni; Av = average

Appendix VIII. Overall performance of sorghum hybrids evaluated across Kiboko, Ukiriguru and Miwaleni during 2011-2012 season

No	Entry	DAF	TL	SS	HT (cm)	PE (cm)	PL (cm)	PW (cm)	PS	AW	GC	PC	Y (t/ha)
1	ICSA 88001 X KARI MTAMA 1	66	1	97.1	227.7	9.2	31.8	11.5	5	0	2	2	6.3
2	ICSA 6 X ICSR 162	67	1	96.4	207.7	7.4	31.9	9.6	6	0	2	2	6.2
3	ATX 623 X IESV 91104 DL	66	1	93.7	213.9	9.0	27.5	9	6	0	2	1	6.2
4	ATX 623 X KARI MTAMA 1	65	1	97.1	209.2	9.5	27.6	8.5	6	0	2	1	6.1
5	ICSA 88006 X KARI MTAMA 1	68	1	97.6	223.9	10.4	30.3	8.2	6	0	2	2	5.2
6	ICSA 44 X IESV 91104 DL	67	1	98.5	221	7.2	25.6	9.9	6	0	2	2	4.9
7	ICSA 12 X IESV 91104 DL	68	1	98.2	235.3	8.9	28.1	9.7	6	0	2	2	4.0
8	SDSA 1 X ICSR 93001	68	1	98.2	212.8	11.2	31.3	8.4	6	0	2	1	3.9
9	ICSA 15 X IESV 91104 DL	68	1	98.4	230.5	9.3	28.1	8.1	6	0	2	2	3.9
10	ICSA 88001 X ICSR 93034	65	2	85.0	241.3	7.3	32.5	10.9	5	0	2	2	3.9
11	ICSA 293 X ICSR 24009	67	1	92.1	170.1	16.1	32.1	10.1	6	0	2	2	3.8
12	ICSA 12 X ICSR 162	66	1	97.4	224	11.4	31.2	8.6	6	0	2	2	3.7
13	ICSA 276 X IESV 91104 DL	67	2	96.2	216.7	12.1	30.3	10.3	5	0	2	2	3.7
14	ATX 623 X ICSR 23019	66	1	94.2	213.6	12.1	31	9.1	6	0	2	1	3.7
15	ICSA 90001 X ICSR 89001	68	1	95.5	141.9	8.8	33.7	9.4	5	0	2	2	3.6
16	ICSA 90001 X ICSR 92003	71	1	98.0	176.8	7.6	33.5	10.5	5	0	2	2	3.5
17	ICSA 12 X KARI MTAMA 1	66	1	97.1	219.6	7.7	28.4	9	6	0	2	2	3.5
18	ICSA 90001 X ICSR 24008	70	1	95.1	172.8	7.6	34.7	11.3	5	0	2	2	3.5
19	ICSA 15 X TEGEMEO	64	1	98.0	233.4	13	29	8.9	5	0	2	2	3.5
20	ICSA 15 X ICSR 162	67	1	96.4	209.2	9.9	33.9	8.8	6	0	2	2	3.4
21	ICSA 6 X IESV 23011 DL	65	2	81.8	219.5	13.9	30	9.9	6	0	2	1	3.4
22	ICSA 11 X S35	61	2	88.7	216.3	14	27.7	7.9	6	0	2	2	3.4
23	IESH ATX623 x GADAM	62	1	98.3	192.3	10.2	27.7	8.1	6	0	3	1	3.4
24	ICSA 88001 X ICSR 160	70	1	97.6	194.3	5.6	33.8	9.7	5	0	1	2	3.4
25	ICSA 90001 X ICSR 172	69	1	93.4	143.8	7.1	32.9	9.6	6	0	2	2	3.4
26	ICSA 44 X MAKUENI LOCAL	64	1	95.7	231.4	12.8	28.7	10.6	5	0	3	1	3.4
27	ATX 623 X IESV 91131 DL	66	1	97.2	162	10.8	30.1	7.8	7	0	2	1	3.3
28	ICSA 89004 X ICSR 89028	69	1	95.1	147.3	7.1	33.2	9.6	5	0	2	2	3.3
29	ICSA 6 X ICSR 93034	66	1	73.1	188.6	8.9	30.9	8.9	6	0	2	1	3.3
30	ICSA 276 X ICSR 162	68	1	97.3	235.9	16.7	30.3	9.2	5	0	2	2	3.2
31	ICSA 15 X ICSR 160	67	1	98.2	183.1	8.6	34.1	8	6	0	2	2	3.2
32	IESA 2 X ICSR 24008	66	1	97.9	178.1	4.1	31.4	10.4	6	0	3	1	3.2
33	ICSA 89003 X IESV 23011DL	67	1	95.3	218.8	16.1	30.5	9.4	5	0	3	1	3.2
34	ICSA 12 X ICSR 172	65	1	95.7	159.2	10.9	29.9	7.4	8	0	2	2	3.2
35	IESH 22009	66	2	97.7	168.3	10.9	31.6	8.1	6	0	2	2	3.1
36	ICSA 12 X IESV 23019 DL	68	1	97.6	238	12.6	32.2	9.3	5	0	3	1	3.1
37	CK60A X IESV 23010 DL	59	1	95.9	194.5	14.7	27.1	7.8	5	0	2	1	3.1
38	ICSA 366 X MACIA	63	1	96.4	162.4	10	28.4	7.8	6	0	3	2	3.1
39	SDSA 1 X BUSIA #28-1	69	1	95.4	228.1	7.3	25.1	7.8	7	0	3	1	3.1
40	ICSA 12 X ICSR 93001	66	1	97.6	186.4	9.8	31.4	8.5	6	0	2	2	3.0
41	ICSA 12 X SIAYA #46-2	68	1	98.7	229.3	6.5	28	8	6	0	2	1	3.0
42	ICSA 276 X ICSR 24008	69	1	96.3	179.2	15.1	31.5	9.1	6	0	2	2	3.0
43	ICSA 687 X IESV 23011 DL	64	3	96.5	176.9	7.3	32.1	11.6	5	0	2	1	3.0
44	ICSA 371 X MACIA	62	1	97.5	181.2	11.7	28	7.8	6	0	3	1	3.0
45	IESH 22002	65	1	98o	164.8	13.5	30.7	7.8	6	0	2	1	3.0
46	CK 60A X KARI MTAMA 1	63	1	96.2	192.5	12.8	26.5	9.3	6	0	2	2	3.0
47	IESH 22019	63	1	89.4	169.6	15.1	26.8	8.2	6	0	2	2	3.0
48	MA 6 X S35	60	2	94.8	204.1	19.5	25	7.4	7	0	2	2	3.0
49	ICSA 11 X ICSR 172	65	1	96.1	154.5	9.8	27.4	7.1	8	0	2	2	3.0
	SEM:	0.9	0.3	2.9	5.0	1.1	0.7	0.4	0.2	0.0	0.2	0.1	0.8
	GM:	66.1	1.1	94.4	188.0	10.5	29.8	8.6	6.0	0.0	2.0	1.5	3.2
	LSD:	2.4	0.9	8.1	13.9	3.0	1.9	1.0	0.7	0.0	0.5	0.2	3.5
	CV	4.1	12.0	10.0	8.1	32.6	6.9	13.9	13.3	38.9	25.7	13.1	12.4

Appendix VIII continues

No	Entry	DAF	TL	SS	HT (cm)	PE (cm)	PL (cm)	PW (cm)	PS	A W	G C	PC	Y (t/ ha)
50	SDSA 1 X IESV 91104 DL	68	1	98.7	246.2	10.6	26.7	7.6	6	0	2	2	3.0
51	IESH 22010	65	1	96.8	166.7	13.6	31.9	7.8	7	0	2	1	3.0
52	ATX 623 X ICSV 95022	64	1	98.1	157.2	9.2	32.7	9.2	5	0	2	1	3.0
53	SDSA 4 X ICSR 43	70	1	98.1	180.5	9.2	35.8	8.6	6	0	2	1	3.0
54	IESA2 X ICSR 24010	66	1	97.7	209.6	11.1	26.2	10.6	5	0	2	2	3.0
55	ICSA 89003 X ICSR 89058	68	1	97.4	164.1	10.3	33.8	8.5	6	0	2	2	3.0
56	MA6 X IESV 23010 DL	61	1	96.8	201.2	17.2	26.5	8	7	0	3	2	2.9
57	IESH 22011	66	2	96.9	168.2	10	30.1	7.9	6	0	2	2	2.9
58	ICSA 90001 X ICSR 43	70	1	95.4	158.8	4.8	35.2	9.6	5	0	2	2	2.9
59	ATX 623 X MACIA	64	2	96.9	172.2	11.7	31.4	8.2	6	0	2	1	2.9
60	ICSA 15 X ICSR 172	65	1	96.1	172.1	10.4	30.6	7	7	0	2	2	2.9
61	ICSA 88001 X MACIA	64	1	97.7	179.1	9.4	31.8	9.2	6	0	2	2	2.9
62	ICSA 366 X KARI MTAMA 1	64	1	96.9	208.1	8.8	27.2	8.4	5	0	2	2	2.8
63	ICSA 77 X ICSR 196	67	1	93.6	175.3	12.7	30.1	8.5	6	0	2	2	2.8
64	ICSA 91002 X ICSR 38	65	1	88.9	147.9	12.5	29.1	8.1	6	0	3	1	2.8
65	ICSA 44 X ICSR 172	68	1	95.1	147.2	12.2	25.1	6.7	8	0	2	2	2.8
66	IESA2 X ICSR 24009	67	1	96.2	146	3.9	29.9	8.6	6	0	2	1	2.8
67	ICSA 88001 X ICSR 108	68	1	98.2	176.5	11	30.9	9.9	5	0	2	2	2.8
68	SDSA1 X ICSR 24010	68	1	97	247.6	11.8	29.1	8.1	6	0	2	1	2.8
69	SDSA 4 X ICSR 89059	69	1	97.7	183	7.1	35.7	7.6	7	0	2	2	2.7
70	ICSA 88006 X ICSR 162	68	1	95.5	215.4	13.4	31.6	8.2	6	0	2	2	2.7
71	ICSA 9 X ICSR 56	65	1	97	191.3	16.1	30	7.5	6	0	2	2	2.7
72	ICSA 11 X SP 74279	61	1	70.6	152.4	14.7	29	6.7	7	0	2	2	2.7
73	ICSA 90001 X ICSR 89058	67	1	96	149.6	7.3	34.3	9.2	6	0	2	2	2.7
74	ICSA 687 X ICSR 162	63	2	96.1	173.8	9.9	30.6	10.2	6	0	2	2	2.7
75	SDSA 1 X IESV 91131 DL	67	1	97.9	174.5	10.5	30.3	6.6	7	0	2	1	2.7
76	ICSA 89003 X ICSR 92003	68	1	98.2	184.6	10.5	31.2	8.1	6	0	2	2	2.7
77	ICSA 376 X IESV 23013 DL	64	1	97	230.8	19.3	27.9	8.5	5	0	3	1	2.7
78	CK 60A X SP 74278	61	1	95.3	161.7	19.5	27.3	7	6	0	3	1	2.7
79	SDSH 90003	62	2	95.9	149.3	12.2	29.3	7.6	6	0	2	1	2.7
80	ATX 623 X MAKUENI LOCAL	63	1	98.3	222.6	11.5	28.8	9.1	6	0	3	1	2.6
81	ICSA 77 X ICSR 108	66	1	88.9	168.1	11.9	29.5	8.9	6	0	2	2	2.6
82	SDSA 1 X ICSR 43	69	1	96.8	187.5	12.7	32.7	7.6	6	0	2	1	2.6
83	SDSA 1 X ICSR 24009	71	1	97.4	181.8	10.5	33.4	7	6	0	2	1	2.6
84	ICSA 9 X ICSR 89058	67	1	97.1	174.9	10.4	33.6	7.6	6	0	2	2	2.6
85	ICSA 77 X ICSR 160	65	1	97.2	170.4	12.8	28.9	9.1	6	0	2	2	2.6
86	IESA 2 X SIAYA#42	67	2	98.6	173.5	3.4	26	7.4	7	0	3	1	2.6
87	ICSA 479 X SIAYA # 66 - 2	69	2	46.4	191.1	4.2	21.7	7.5	7	1	2	2	2.6
88	IESA 2 X ICSR 24007	63	1	86.7	135	8.1	27.9	8.6	6	0	2	1	2.6
89	ICSA 88006 X IESV 91131 DL	68	1	96	152.7	11.5	30.2	6.9	6	0	2	2	2.5
90	ICSA 90001 X ICSR 162	68	1	86.2	179.5	10.7	30.6	8	6	0	2	2	2.5
91	ICSA 654 X ICSR 153	62	3	62.4	169.7	14	28.2	7	7	0	3	2	2.5
92	MA 6 X MAKUENI LOCAL	61	1	89.2	226.9	19.8	28.1	8.3	5	0	3	1	2.5
93	SDSA 4 X ICSR 24009	71	1	96.7	194.3	8.8	33.3	7.3	7	0	2	1	2.4
94	IS 8193	69	1	96.4	168.3	3.2	23.4	7.1	7	0	3	1	2.2
95	WAHI	67	1	96.5	117.9	3.6	28.3	7.6	7	0	2	2	2.4
96	TEGEMEO	71	1	98.8	159.5	4.3	22.7	8.7	6	0	2	2	2.9
97	MACIA (check)	71	1	98.6	225.8	3.1	21.3	9.9	5	0	3	1	2.7
	SEM:	0.9	0.3	2.9	5.0	1.1	0.7	0.4	0.2	0.0	0.2	0.1	0.8
	GM:	66.1	1.1	94.4	188.0	10.5	29.8	8.6	6.0	0.0	2.0	1.5	3.2
	LSD:	2.4	0.9	8.1	13.9	3.0	1.9	1.0	0.7	0.0	0.5	0.2	3.5
	CV	4.1	12	10.0	8.1	32.6	6.9	13.9	13	38	26	13	12

Appendix IX. Mean performance of sorghum hybrids evaluated at Ukiriguru during 2011/2012

No	Entry	DAF	TL	SS (%)	HT(cm)	PE (cm)	PL (cm)	PW (cm)	PS	AW	GC	Y (t/ha)
1	ICSA 88006 X KARI MTAMA 1	75	0	96.5	173.3	8.1	25.5	7.2	4	0	3	6.9
2	ICSA 88001 X KARI MTAMA 1	65	0	96.7	189.9	14.1	28.9	13.6	3	0	3	6.2
3	ICSA 12 X IESV 91104 DL	73	0	98.2	183.5	16.4	26.4	9	4	0	3	6.0
4	ICSA 88001 X ICSR 93034	66	1	83	195.5	9	30.7	13.1	3	0	3	6.0
5	ICSA 366 X MACIA	64	1	93.2	137	18.2	23	6.7	4	0	2	4.4
6	ICSA 90001 X ICSR 24008	73	0	90.7	150.2	8.9	32.8	13	3	0	4	4.2
7	ICSA 12 X ICSR 162	67	0	97.5	174.8	16.4	27.9	9.5	3	0	2	4.2
8	ICSA 6 X ICSR 162	70	0	94.9	180.3	13.7	27.7	8.3	4	0	3	4.2
9	ICSA 90001 X ICSR 172	71	0	96.9	133	10.9	30.8	10.6	3	0	3	4.0
10	ICSA 15 X ICSR 162	69	0	91.9	183.9	15.8	30.2	7.8	4	0	4	4.0
11	ICSA 44 X IESV 91104 DL	74	0	98.8	189.1	9.8	24.8	10.4	3	0	3	3.8
12	IESH 22009	66	0	97.5	128.9	16	27.4	7.6	4	0	3	3.7
13	IESH ATX623 x GADAM	65	0	99.1	158.9	16.7	22.7	7.5	4	0	3	3.7
14	ICSA 276 X ICSR 24008	73	0	91.3	132.8	22.1	27.5	8.7	3	0	4	3.7
15	SDSA 1 X ICSR 93001	72	0	98.2	169.1	17.5	25.9	7.2	6	0	3	3.6
16	ICSA 44 X ICSR 172	75	1	97.9	133.3	17	23.1	7.1	6	0	5	3.6
17	ICSA 12 X ICSR 93001	66	0	95.6	152.5	13.6	27.5	7.9	4	0	3	3.6
18	ICSA 293 X ICSR 24009	67	0	97.8	141.5	25.4	26	8.3	3	0	4	3.5
19	ICSA 12 X IESV 23019 DL	75	0	97.6	194.4	16.5	30.1	9.7	3	0	2	3.4
20	ICSA 88001 X ICSR 160	77	1	97.1	195.3	6.4	27.6	7.8	4	0	2	3.4
21	ICSA 15 X TEGEMEO	66	1	98.2	182	12.9	25.6	9	3	0	3	3.3
22	ICSA 90001 X ICSR 89058	69	1	91.8	137.2	6.6	30.8	8.8	4	0	4	3.3
23	ICSA 89003 X IESV 23011DL	72	0	94.3	171.7	19.9	27.8	9.1	3	0	2	3.3
24	MA 6 X S35	60	0	89.8	158.2	22.1	20.3	6.5	6	0	3	3.3
25	SDSA 1 X BUSIA #28-1	75	0	97.1	188.9	4.7	25.4	8.1	5	0	3	3.3
26	ICSA 11 X S35	61	0	69.6	165.3	24.1	23.1	7.4	4	0	3	3.2
27	ICSA 15 X ICSR 160	72	0	98.4	158.9	13.1	28.2	6.9	5	0	3	3.2
28	ICSA 89004 X ICSR 89028	76	0	93.4	134.1	12.7	30.2	9.2	3	0	4	3.2
29	IESH 22010	69	1	96.8	134.2	18.7	27.7	6.6	6	0	3	3.2
30	ATX 623 X ICSV 95022	64	0	97.8	136.7	17.3	28.3	10.1	3	0	1	3.2
31	ATX 623 X IESV 91131 DL	72	0	96.8	131.9	17.3	25.3	7	5	0	3	3.2
32	SDSH 90003	61	0	93.8	129.3	18.3	26.1	7	4	0	1	3.2
33	ATX 623 X KARI MTAMA 1	69	0	98.6	162.9	18.5	24.9	7.7	4	0	2	3.2
34	ICSA 479 X SIAYA # 66 - 2	71	0	18.7	141.9	3	18.7	6.8	4	1		3.2
35	ICSA 90001 X ICSR 162	69	0	94.2	147.2	20.6	27	7.1	4	0	3	3.1
36	ICSA 12 X ICSR 172	67	0	94.3	133.9	16.7	23.6	5.6	6	0	3.7	3.1
37	ICSA 276 X IESV 91104 DL	69	0	94.7	173.7	22.7	24.2	8.8	3	0	3	3.1
38	SDSA1 X ICSR 24010	73	0	96.3	192.5	19.1	25.8	8.9	3	0	3	3.1
39	ATX 623 X IESV 91104 DL	68	0	48.2	137.1	15	26.7	8.4	4	0	3	3.1
40	ICSA 687 X ICSR 162	68	0	95.2	153.7	12.3	27.3	10.8	3	0	4.3	3.1
41	SDSA 1 X IESV 91104 DL	76	0	98.8	221.1	12.3	25.2	6.7	4	0	3	3.1
42	SDSA 4 X ICSR 89059	75	0	97.5	156.3	9.6	33.1	7.9	5	0	3	3.1
43	ICSA 44 X MAKUENI LOCAL	68	0	99.1	198.3	17.1	25.8	11.7	3	0	2	3.1
44	ATX 623 X ICSR 23019	67	0	94.3	175.3	18.7	26.5	9.3	4	0	1.7	3.0
45	IESA 2 X ICSR 24008	71	0	97.4	119.1	3.7	26.6	9.7	3	0	4.3	3.0
46	ICSA 15 X IESV 91104 DL	77	0	98.2	187.4	11	25.2	6.4	4	0	3	3.0
47	IESH 22002	68	0	98.4	133.5	22.2	26.8	6.9	5	0	3	3.0
48	ICSA 89003 X ICSR 89058	74	0	96.3	146.7	14.4	29	8.2	4	0	3	3.0
49	ICSA 376 X IESV 23013 DL	65	0	95	180.3	24.3	24	9.5	3	0	2	3.0
50	ICSA 90001 X ICSR 43	78	0	97.5	151.5	6	31	8.6	3	0	3.7	3.0
	Mean	70	0.2	93.4	154.4	15.1	26.1	8.1	4.4	0	3	3.1
	SEm+/-	2.3	1.2	5.9	6.8	2.4	1.1	0.7	0.4	0.0	0.4	1.4
	CV(%)	5.7	23	11.0	7.6	27.5	7.5	15.3	16	0.0	21	4.8

Appendix IX continues

No	Entry	DAF	TL	SS (%)	HT(cm)	PE (cm)	PL (cm)	PW (cm)	PS	AW	GC	Y (t/ha)
51	ATX 623 X MAKUENI LOCAL	68	0	98.4	188.0	20.7	26	10.6	3	0	2	3
52	ICSA 12 X KARI MTAMA 1	71	1	96.6	159.9	9.5	26.7	8.7	3	0	3	3.0
53	ICSA 6 X ICSR 93034	71	1	97.8	152.1	15.6	30.5	8.4	4	0	3	3.0
54	ATX 623 X MACIA	65	0	97.1	138.9	18.9	27.1	7.7	6	0	3	3.0
55	ICSA 88001 X MACIA	65	0	96.9	142.3	15.8	27.9	9.3	3	0	4	2.9
56	ICSA 687 X IESV 23011 DL	67	0	94	160.9	12.1	27.7	11.1	3	0	2	2.9
57	ICSA 276 X ICSR 162	72	0	95.8	168.7	23.2	25.8	8.8	3	0	4	2.8
58	ICSA 11 X SP 74279	59	0	94.8	127.1	27.5	19.8	5.3	6	0	2	2.7
59	ICSA 90001 X ICSR 89001	72	0	90.1	123.1	13.7	28.9	7.6	3	0	3	2.7
60	IESH 22011	68	0	95.1	131.7	12.3	26.9	7.5	6	0	3	2.7
61	SDSA 1 X ICSR 43	73	0	96.4	165.4	22.1	29.7	6.8	5	0	3	2.7
62	ICSA 77 X ICSR 160	65	0	97.7	130.9	18.4	24	9.7	3	0	5	2.7
63	ICSA 77 X ICSR 108	66	0	67.2	122.7	15.4	26.2	9.2	3	0	4	2.7
64	ICSA 90001 X ICSR 92003	78	0	97.2	168.8	11	30.8	9.4	3	0	3	2.7
65	CK 60A X KARI MTAMA 1	66	3	95	161.7	20.1	22.5	10.1	3	0	3	2.7
66	ICSA 9 X ICSR 56	68	0	97	160.5	21.4	26.9	7.3	4	0	3	2.7
67	MA 6 X MAKUENI LOCAL	64	1	96.3	184.4	24	25.3	9.3	3	0	2	2.6
68	MA6 X IESV 23010 DL	64	0	94.9	151.6	21.8	21.6	7.5	3	0	2	2.6
69	ICSA 371 X MACIA	63	0	96.1	132.5	16.2	22.1	6.2	4	0	2	2.6
70	ICSA 6 X IESV 23011 DL	68	0	60.2	166.1	18.7	25.3	8.6	4	0	2	2.6
71	ICSA 89003 X ICSR 92003	71	2	98.6	157.8	16.3	29	8.3	4	0	3	2.6
72	SDSA 4 X ICSR 43	74	0	98.5	158.1	17.9	30.3	7.9	4	0	3	2.6
73	ICSA 11 X ICSR 172	68	0	92.8	131.3	15.1	23.8	6.2	6	0	5	2.5
74	IESA2 X ICSR 24010	72	0	97.4	177.7	16.1	23	11.5	3	0	4	2.5
75	ICSA 91002 X ICSR 38	66	0	67.5	104.2	23.7	20.1	6	4	0	2	2.5
76	SDSA 4 X ICSR 24009	74	0	95.2	164.9	12.7	30.4	6.2	6	0	3	2.5
77	SDSA 1 X IESV 91131 DL	73	0	97.8	151.4	17.2	26.9	5.6	6	0	3	2.4
78	ICSA 15 X ICSR 172	72	0	93	125.7	11.1	26.1	5.7	6	0	3	2.4
79	SDSA 1 X ICSR 24009	78	0	97.4	155.7	17.5	30.3	5.4	5	0	3	2.4
80	IESH 22019	65	0	91.6	128.2	20.7	20.1	6.3	6	0	3	2.4
81	ICSA 88006 X IESV 91131 DL	75	0	95.5	135.9	13.6	28.2	6.1	4	0	3	2.4
82	CK60A X IESV 23010 DL	55	0	91.1	156.5	25.5	23	7.9	3	0	2	2.4
83	IESA2 X ICSR 24009	71	0	96.5	126.1	3.7	26.6	7.3	5	0	3	2.3
84	ICSA 366 X KARI MTAMA 1	68	0	95.8	162.9	10.5	23.6	8.4	3	0	2	2.3
85	ICSA 12 X SIAYA #46-2	76	0	99.4	178	4.3	24.2	7	4	0	2	2.3
86	ICSA 88006 X ICSR 162	73	0	97.2	181.5	16.9	29.1	8.4	4	0	4	2.3
87	ICSA 88001 X ICSR 108	74	0	98.4	139.4	18.1	25.5	9.4	3	0	4	2.3
88	CK 60A X SP 74278	60	0	92.7	133.6	27.6	21.4	6	5	0	2	2.3
89	IS 8193	78	0	99.7	153.1	2.3	21.4	6.4	6	0	4	2.3
90	ICSA 654 X ICSR 153	61	3	94.5	123	20.4	21.3	5.2	6	0	2	2.2
91	ICSA 77 X ICSR 196	69	0	86.6	145.2	23.1	25.4	7.2	4	0	4	2.2
92	IESA 2 X SIAYA#42	77	1	99.8	158.6	2.5	23.5	6.5	5	0	3	2.1
93	ICSA 9 X ICSR 89058	76	0	97.2	156.1	14.8	29.3	6.6	5	0	3	2.1
94	IESA 2 X ICSR 24007	66	0	94.1	114.7	9.8	21.3	7.4	5	0	3	1.8
	WAHI	71	0	97.9	95.7	3.3	25.9	7.6	6	0	5	2.5
	TEGEMEO	79	0	99.2	139	3.5	20.6	8.3	5	0	4	2.7
	MACIA (check)	78	3	98.5	179.5	2.4	19.9	10.2	3	0	2	2.9
	Mean	70	0.2	93.4	154.4	15.1	26.1	8.1	4.4	0	3	3.1
	SEm+/-	2.3	1.2	5.9	6.8	2.4	1.1	0.7	0.4	0.0	0	1.4
	CV(%)	5.7	23.6	11.0	7.6	27.5	7.5	15.3	16	0.0	21	4.8

Appendix X. Mean performance for Hybrids at Kiboko during 2011/2012 growing seasons

No	Entry	DAF	TL	SS	HT	PE	PL	PW	PS	AW	GC	Y(t/ha)
1	ICSA 88001 X ICSR 93034	66	0	69.3	267.7	6.4	34.7	13.4	5	0	1	6.7
2	ATX 623 X IESV 91104 DL	66	0	99.8	248.8	7.7	27.7	10.6	8	0	1	6.6
3	ICSA 88001 X KARI MTAMA 1	66	0	98.3	251.9	7.8	32.7	13.4	6	0	1	6.2
4	ICSA 276 X IESV 91104 DL	67	0	97.5	220.6	9.1	34.7	14.3	6	0	1	6.1
5	ATX 623 X KARI MTAMA 1	64	0	98	237.9	5.8	29.2	10.9	7	0	1	5.9
6	ICSA 6 X ICSR 93034	68	0	95.3	232.8	5.3	31.7	12.3	7	0	1	5.7
7	ICSA 90001 X ICSR 24008	71	0	98.7	188.1	4.6	36.5	14.9	6	0	1	5.6
8	ICSA 12 X IESV 91104 DL	67	0	99.4	258.6	7.6	31.1	12.7	6	0	1	5.5
9	ICSA 293 X ICSR 24009	68	0	99.2	196.3	18.2	38.3	16	6	0	1	5.5
10	ICSA 6 X ICSR 162	66	0	98.8	212	4.2	34	11.9	8	0	1	5.4
11	ICSA 6 X IESV 23011 DL	65	0	82.8	225.8	9.1	33.3	13.2	5	0	1	5.1
12	ICSA 44 X IESV 91104 DL	66	0	99.3	233.5	8.3	25.9	11.2	7	0	1	5.1
13	ICSA 276 X ICSR 162	67	0	99	267.3	18.3	33.6	12.1	6	0	1	5.1
14	ICSA 88001 X ICSR 160	67	0	97.7	189.7	4.3	35.8	14.1	5	0	1	4.9
15	ICSA 12 X KARI MTAMA 1	66	0	98.2	248.7	8.3	29.1	10.8	7	0	1	4.8
16	IESH 22019	63	1	82	178.4	13.1	31.7	11.5	7	0	1	4.8
17	ICSA 90001 X ICSR 172	71	0	87.7	158.3	0.9	34.7	11.3	8	0	1	4.7
18	ICSA 89003 X ICSR 89058	66	0	99.7	191.1	13.3	37.6	11.3	7	0	1	4.7
19	ICSA 12 X SIAYA #46-2	66	0	98.9	251.7	9.7	30	9.8	8	0	2	4.7
20	IESH 22002	64	0	99	174	11.3	33.1	10.1	8	0	1	4.6
21	ICSA 88006 X KARI MTAMA 1	65	0	99.7	243.1	15.8	29.7	8.9	8	0	1	4.6
22	ICSA 90001 X ICSR 89001	65	0	97.8	150.3	2.5	36.8	11.5	5	0	1	4.6
23	ICSA 12 X ICSR 162	65	4	98.6	250.9	14.1	32.1	9.1	6	0	1	4.6
24	ICSA 366 X MACIA	62	0	98.4	170.3	5.9	33.7	11.1	6	0	2	4.6
25	IESA2 X ICSR 24009	64	0	98.4	152.3	1.8	33.3	12.1	6	0	1	4.6
26	ICSA 88001 X ICSR 108	64	0	98.6	192.9	9.5	34.2	13.9	6	0	1	4.5
27	IESA 2 X ICSR 24008	68	0	98.5	149.3	0.5	35.9	15.5	6	0	1	4.5
28	SDSA 1 X ICSR 93001	66	1	99.1	239.5	10.5	33.3	9.9	6	0	1	4.5
29	ICSA 88006 X ICSR 162	66	0	94.9	228.5	14.6	33.3	10	6	0	1	4.5
30	ICSA 15 X ICSR 160	64	0	99.2	192.7	6.9	34.7	10.1	8	0	1	4.5
31	SDSA 1 X BUSIA #28-1	68	0	91.8	230.1	9.9	26.8	9	8	0	2	4.5
32	ICSA 15 X IESV 91104 DL	65	0	99.9	237.9	13	29.7	9.9	8	0	1	4.5
33	ATX 623 X IESV 91131 DL	65	0	98.1	175.9	8.4	32	9.7	7	0	1	4.4
34	ICSA 371 X MACIA	62	0	99.2	199.4	13.9	32.1	10	7	0	2	4.4
35	IESH 22023	60	0	99.7	207.7	8.5	30.8	9.7	7	0	1	4.4
36	SDSA 1 X IESV 91104 DL	65	0	99.5	246	12.1	27.9	9.5	6	0	1	4.4
37	ICSA 276 X ICSR 24008	68	0	99.2	195.7	14.7	34.2	12.4	7	0	1	4.4
38	ATX 623 X ICSV 95022	66	0	99.9	163.3	4	36.6	11.3	6	0	2	4.4
39	SDSA 4 X ICSR 43	69	0	99.4	182.5	4.4	38.1	10.5	7	0	1	4.4
40	ICSA 15 X ICSR 162	68	0	98.9	245.1	8.4	34.2	10.5	6	0	1	4.3
41	ICSA 89003 X IESV 23011DL	66	0	93.7	237.1	18.5	33.3	12.8	4	0	4	4.3
42	ICSA 90001 X ICSR 92003	70	0	98.6	177.1	6.3	34.9	13.4	6	0	1	4.3
43	ICSA 11 X ICSR 172	63	0	99	157.3	10.4	29.2	8.3	6	0	1	4.3
44	ICSA 366 X KARI MTAMA 1	65	0	98.2	227.4	7.5	29.3	10	6	0	2	4.3
45	ICSA 91002 X ICSR 38	64	0	97.8	156.7	7.2	34.1	11.8	7	0	2	4.2
46	IESH 22010	65	0	97.9	175.7	11.1	36.1	10.1	8	0	1	4.2
47	ATX 623 X ICSR 23019	65	0	98.6	247.5	12.1	34	10.5	7	0	1	4.2
48	ICSA 687 X IESV 23011 DL	65	0	98.8	183.3	4.7	34.6	16.7	5	0	1	4.2
49	ICSA 12 X IESV 23019 DL	67	0	98.8	264.3	14.1	34.5	11.8	6	0	2	4.2
50	SDSA1 X ICSR 24010	64	0	98.5	264.5	11	30.1	9.6	7	0	1	4.2
	Mean	72	0	99.8	221.8	1.3	21.3	12.5	5	0	1.7	4.2
	SEm+/-	72	2.7	99.9	267.7	24.1	38.3	16.7	9	1	3.7	1.8
	CV(%)	1.46	0.24	7.75	12.13	2.49	1.34	0.98	0.78	0.01	0.34	17.3

Appendix X continues

No	Entry	DAF	TL	SS	HT	PE	PL	PW	PS	AW	GC	Y(t/ha)
51	ICSA 89003 X ICSR 92003	66	0	99.5	191.0	11.1	32.8	10	7	0	1	4.1
52	ICSA 44 X MAKUENI LOCAL	61	0	99.2	259.3	16.2	29.8	12.9	5	0	2	4.1
53	ICSA 89004 X ICSR 89028	66	0	95.6	148.3	3.5	33.3	12.5	6	0	1	4.1
54	CK60A X IESV 23010 DL	62	0	98.9	212.3	13	27.5	9.1	7	0	1	4.1
55	ICSA 15 X TEGEMEO	63	0	98.7	247.6	16.6	29.9	10.3	7	0	1	4
56	ICSA 12 X ICSR 172	64	0	97.5	166.7	12.7	31.3	9.2	9	0	1	4
57	IESH 22009	65	0	98.8	185.1	11.3	34.3	9.5	8	0	1	4
58	ICSA 11 X S35	61	0	96.8	235.5	12.7	30.3	9.3	7	0	1	4
59	ICSA 9 X ICSR 89058	63	0	98.5	180.6	12.7	36.8	9.9	6	0	1	4
60	IESA2 X ICSR 24010	63	0	98.6	252.7	11.6	26.5	13.3	6	0	1	4
62	ICSA 88001 X MACIA	66	0	99.1	178.3	33.1	11.9	7	0	2	1	3.9
63	ICSA 77 X ICSR 196	61	0	96.6	187.6	32.3	10.7	8	0	2	1	3.9
64	SDSA 4 X ICSR 89059	70	0	99.4	191.1	37.6	8.9	9	0	1	1	3.9
65	ICSA 77 X ICSR 160	66	0	97.5	189.3	30.5	11.7	7	0	2	1	3.9
66	IESH 22011	67	0	98.3	182.6	32.7	9.5	7	0	2	1	3.8
67	ICSA 9 X ICSR 56	63	0	97.3	201.3	33.1	9	8	0	2	1	3.8
68	ICSA 90001 X ICSR 43	71	0	90.9	156.5	37.8	13.3	7	0	1	1	3.8
69	ICSA 77 X ICSR 108	68	0	98.9	186.1	32.3	10.9	8	0	2	1	3.8
70	MA6 X IESV 23010 DL	66	0	98.7	218.3	29.1	9.3	8	0	3	2	3.8
71	ICSA 15 X ICSR 172	66	0	98.2	170.7	32.1	8.4	9	0	2	1	3.7
72	CK 60A X KARI MTAMA 1	70	0	97.4	199.8	28.3	10	7	0	3	1	3.7
73	ICSA 12 X ICSR 93001	69	0	99.3	194.8	33.1	10.4	7	0	2	1	3.7
74	ATX 623 X MACIA	63	0	96.3	179.9	33.5	9.7	7	0	2	1	3.7
75	SDSA 1 X IESV 91131 DL	60	0	98.5	178.6	31.7	7.8	8	0	2	1	3.7
76	ICSA 687 X ICSR 162	62	0	97.8	179.1	33.3	13.3	6	0	3	1	3.7
77	ICSA 654 X ICSR 153	68	0	13.4	178.9	33.3	9.6	8	0	3	2	3.6
78	SDSA 1 X ICSR 24009	60	0	98.6	201.5	34.7	9.4	8	0	2	1	3.6
79	CK 60A X SP 74278	63	0	96.3	173.2	30.3	8.6	7	0	2	2	3.5
80	IESA 2 X SIAYA#42	67	0	99.8	179.7	27.1	8.5	8	0	2	2	3.5
81	ICSA 44 X ICSR 172	66	0	94.5	182.2	14.3	25.7	6.4	8	0	1	3.5
82	SDSA 4 X ICSR 24009	68	0	91.3	157.1	13.6	27.1	7.7	8	0	1	3.4
83	ICSA 90001 X ICSR 89058	70	0	98.8	206.9	8.9	37.9	9.9	8	0	1	3.4
84	ICSA 11 X SP 74279	67	0	98.6	155.1	5.5	36.1	11.5	7	0	1	3.3
85	ATX 623 X MAKUENI LOCAL	62	0	74.2	162	13.4	32	8.2	8	0	1	3.3
86	MA 6 X S35	62	0	99.8	237.5	8.6	29.3	9.6	7	0	2	3.2
87	SDSH 90003	60	0	97.2	217.9	24.1	27.9	8	8	0	1	3.2
88	ICSA 479 X SIAYA # 66 - 2	62	0	98.3	163.6	12.7	30.5	9.1	8	0	2	3.2
89	ICSA 88006 X IESV 91131 DL	68	3	47.7	194.7	2.1	23.4	9	8	1	1	3.2
90	SDSA 1 X ICSR 43	65	0	98.8	150.7	12.7	31.3	7.8	9	0	1	3.1
91	ICSA 90001 X ICSR 162	68	0	99.6	197.5	9	30.8	8.4	8	0	1	3.1
92	IESA 2 X ICSR 24007	69	0	63.1	183.6	2.9	32.9	10.4	7	0	1	2.9
93	MA 6 X MAKUENI LOCAL	61	0	88.3	141.3	7.7	29.9	11	7	0	1	2.6
94	IS 8193	60	0	99	239.6	20.9	29.7	9.1	6	0	2	2.6
95	WAHI	67	0	92.1	175.4	0.5	24.1	8.2	8	0	2	2.5
96	TEGEMEO	68	0	93.1	120.1	1.7	30.1	8.7	7.7	0	1	2.9
97	MACIA (check)	71	0	99.5	158.6	2.1	23.1	10.7	7.6	0	1	3.6
	Mean	72	0	99.8	221.8	1.3	21.3	12.5	5	0	1.7	4.2
	SEm+/-	72	2.7	99.9	267.7	24.1	38.3	16.7	9	1	3.7	1.8
	CV(%)	1.46	0.24	7.75	12.13	2.49	1.34	0.98	0.78	0.01	0.34	17.3

Appendix XI. Mean performance of sorghum hybrids evaluated at Miwaleni in 2011/2012 seasons

No	Entry	DAF	TL	SS (%)	HT (cm)	PE (cm)	PL (cm)	PW (cm)	PS	AW	GC	Y (t/ha)
1	ICSA 15 X IESV 91104 DL	62	0	98.7	269.6	3.5	29.3	7.7	6.0	0.0	1.0	6.1
2	SDSA 1 X ICSR 93001	67	0	98.8	231.9	5.7	35.0	8.3	6.0	0.0	1.0	5.7
3	ICSA 6 X ICSR 162	67	0	96.4	232.4	3.4	34.3	8.9	6.0	0.0	1.0	5.5
4	ATX 623 X ICSR 23019	64	0	89.5	220	5.9	32.6	7.6	8.0	0.0	3.0	5.5
5	ATX 623 X KARI MTAMA 1	61	0	95.8	228.5	3.8	28.2	6.7	6.0	0.0	1.0	5.4
6	ICSA 44 X IESV 91104 DL	62	0	99.4	243.3	2.6	25.3	8.5	7.0	0.0	1.0	5.3
7	ATX 623 X IESV 91104 DL	62	0	98.1	257.9	3.9	27.8	8.0	7.0	0.0	1.0	5.1
8	ICSA 90001 X ICSR 92003	65	0	99.6	183.5	4.7	35.5	9.4	6.0	0.0	1.0	5.1
9	ICSA 90001 X ICSR 89001	68	0	99	148.4	9.7	36.0	9.2	6.0	0.0	1.0	4.9
10	ICSA 88001 X KARI MTAMA 1	65	0	97.6	244.7	5.2	34.1	8.4	6.0	0.0	1.0	4.6
11	ICSA 15 X TEGEMEO	63	0	98.6	274.5	10.2	31.4	7.5	6.0	0.0	1.0	4.5
12	ICSA 88006 X KARI MTAMA 1	65	0	98.1	258.3	7.1	35.6	8.4	7.0	0.0	1.0	4.5
13	ICSA 11 X S35	59	0	97.1	250.3	6.0	29.3	6.6	8.0	0.0	1.0	4.3
14	ICSA 12 X IESV 91104 DL	64	0	98.6	267.6	2.4	26.7	7.7	7.0	0.0	1.0	4.2
15	ICSA 12 X ICSR 162	65	0	97.5	249.4	4.0	33.9	7.2	7.0	0.0	1.0	4.1
16	ICSA 12 X KARI MTAMA 1	62	0	97.9	252.9	4.7	29.3	7.5	7.0	0.0	1.0	4.1
17	ICSA 293 X ICSR 24009	67	0	78.2	171	6.2	32.3	6.4	7.0	0.0	1.0	4.1
18	ICSA 6 X IESV 23011 DL	62	0	96.6	269.1	14.6	31.4	8.2	7.0	0.0	4.0	4.0
19	ICSA 44 X MAKUENI LOCAL	63	0	89.2	240.3	5.8	30.4	8.1	6.0	0.0	4.0	4.0
20	CK60A X IESV 23010 DL	57	0	98.4	215.3	6.6	30.3	6.2	6.0	0.0	3.0	3.8
21	ICSA 15 X ICSR 162	66	0	99.4	200.2	5.4	37.9	8.1	6.0	0.0	1.0	3.6
22	ICSA 276 X IESV 91104 DL	66	0	97.2	258	4.8	32.1	8.3	7.0	0.0	1.0	3.5
23	ICSA 89004 X ICSR 89028	65	0	96.7	156.2	4.2	36.5	7.4	6.0	0.0	1.0	3.5
24	CK 60A X KARI MTAMA 1	59	0	96.9	216.3	8.0	28.0	7.9	7.0	0.0	3.0	3.4
25	ICSA 12 X ICSR 172	63	0	95.8	174.7	3.5	34.9	7.1	9.0	0.0	1.0	3.4
26	IESH ATX623 x GADAM	58	0	97.7	210.7	5.3	29.2	7.0	6.0	0.0	4.0	3.4
27	ATX 623 X IESV 91131 DL	62	0	97.9	175.9	6.8	33.1	6.6	7.0	0.0	1.0	3.4
28	MA 6 X S35	58	0	97.6	237.6	14.5	26.1	7.4	6.0	0.0	1.0	3.3
29	IESA 2 X ICSR 24008	60	0	99.5	265.2	6.4	31.9	6.4	6.0	0.0	4.0	3.1
30	ICSA 15 X ICSR 160	65	0	98.8	197.4	5.3	40.0	7.0	6.0	0.0	1.0	3.1
31	ICSA 15 X ICSR 172	60	0	97.8	218.7	5.7	33.9	6.5	6.0	0.0	1.0	3.0
32	IESA2 X ICSR 24010	63	0	98.4	200.1	5.8	28.5	7.6	6.0	0.0	1.0	3.0
33	ICSA 89003 X IESV 23011DL	63	0	98.4	250.2	11.1	30.6	6.7	8.0	0.0	4.0	3.0
34	ICSA 88001 X ICSR 160	66	0	99.3	198.4	5.0	38.5	7.7	6.0	0.0	1.0	3.0
35	MA6 X IESV 23010 DL	58	0	97.7	234.9	15.8	28.2	7.0	8.0	0.0	4.0	3.0
36	ICSA 687 X IESV 23011 DL	60	0	97.8	185.6	4.2	34.3	8.1	6.0	0.0	4.0	3.0
37	IESA 2 X ICSR 24007	62	0	74.2	144.8	6.1	32.4	7.4	6.0	0.0	1.0	2.9
38	ICSA 12 X SIAYA #46-2	64	0	99.6	261.6	4.3	29.4	7.1	6.0	0.0	3.0	2.9
39	ICSA 371 X MACIA	61	0	98.7	211.3	5.4	29.5	6.8	6.0	0.0	4.0	2.9
40	ICSA 12 X ICSR 93001	64	0	99.3	211.7	5.8	33.9	7.3	6.0	0.0	1.0	2.9
41	IESH 22009	65	0	98.3	189.1	5.3	33.2	7.3	6.0	0.0	1.0	2.8
42	ICSA 11 X ICSR 172	63	0	97.2	172	3.7	28.9	6.4	9.0	0.0	1.0	2.8
43	ICSA 276 X ICSR 162	66	0	98.4	275.5	10.1	31.4	6.8	6.0	0.0	1.0	2.8
44	ICSA 12 X IESV 23019 DL	62	0	97.8	259.4	7.9	32.3	6.7	6.0	0.0	4.0	2.8
45	IESH 22011	64	0	98.3	188.7	6.9	30.8	6.6	6.0	0.0	1.0	2.8
46	ATX 623 X MACIA	63	0	98.5	196.5	4.8	33.8	7.1	6.0	0.0	1.0	2.7
47	ICSA 77 X ICSR 196	66	0	97.2	192	4.1	32.7	7.5	6.0	0.0	1.0	2.7
48	SDSA 4 X ICSR 43	66	0	98	200.5	5.0	40.0	7.4	6.0	0.0	1.0	2.6
49	ICSA 11 X SP 74279	59	0	32.3	165	4.4	35.2	6.1	6.0	0.0	4.0	2.6
50	ICSA 90001 X ICSR 172	64	0	95.1	136.6	8.7	33.5	7.3	6.0	0.0	1.0	2.6
	Mean	63	0	94.6	209	6.8	31.4	6.9	6.5	0	1.8	3.0
	SEm+/-	0.95	0.01	4.73	10.37	1.59	1.41	0.6	0.37	0.03	0.25	0.04
	CV(%)	2.61	34	8.67	8.6	40.5	7.8	15.1	9.9	46	23.9	21

Appendix XI continues

No	Entry	DAF	TL	SS (%)	HT (cm)	PE (cm)	P(cm)L	PW (cm)	PS	AW	GC	Y (t/ha)
51	ICSA 88001 X ICSR 93034	62	0	98.6	265.1	5.7	32.7	6.9	7.0	0.0	1.0	2.6
52	ICSA 90001 X ICSR 43	65	0	98.3	166	5.1	37.6	7.4	6.0	0.0	1.0	2.6
53	CK 60A X SP 74278	60	0	97.5	176.2	15.7	29.7	5.8	6.0	0.0	4.0	2.6
54	IESH 22019	61	0	92.3	200.6	12.8	28.1	6.6	7.0	0.0	1.0	2.5
55	SDSA 1 X ICSR 43	66	0	95.5	199.6	7.5	38.1	7.3	6.0	0.0	1.0	2.4
56	SDSA 1 X BUSIA #28-1	66	0	97.5	268.5	6.6	22.5	6.0	8.0	0.0	3.0	2.4
57	ICSA 88001 X MACIA	65	0	98.5	215.8	4.9	34.6	6.5	6.0	0.0	1.0	2.4
58	SDSA 1 X IESV 91131 DL	63	0	98.8	192.3	4.9	32.4	5.8	6.0	0.0	1.0	2.4
59	ICSA 366 X KARI MTAMA 1	59	0	97.9	235.6	7.9	28.2	6.7	6.0	0.0	2.0	2.4
60	ICSA 90001 X ICSR 24008	68	0	96.1	178.9	8.5	35.4	7.0	6.0	0.0	1.0	2.3
61	ATX623 X ICSR 56	62	0	97.9	184.8	7.8	32.4	6.1	6.0	0.0	1.0	2.3
62	CK 60A X ICSR 89058	61	0	96.9	188.5	11.7	32.1	6.4	6.0	0.0	1.0	2.3
63	IESA 2 X SIAYA#42	61	0	97.9	180.9	6.0	26.7	6.9	8.0	0.0	4.0	2.3
64	SDSA 1 X IESV 91104 DL	63	0	99.6	276.5	7.5	26.6	6.4	6.0	0.0	1.0	2.2
65	ATX 623 X MAKUENI LOCAL	60	1	98.3	245.1	5.5	30.9	7.1	7.0	0.0	4.0	2.2
66	MA 6 X MAKUENI LOCAL	57	0	69.8	259.9	16.8	29.0	6.5	6.0	0.0	4.0	2.2
67	ICSA 6 X ICSR 93034	61	0	16.7	181.1	5.4	30.5	6.2	6.0	0.0	1.0	2.2
68	ICSA 9 X ICSR 56	63	0	97.7	212.3	10.9	30.1	5.8	6.0	0.0	1.0	2.1
69	SDSA 1 X ICSR 24009	66	0	97.4	187.6	4.1	35.6	5.6	6.0	0.0	1.0	2.1
70	IESA2 X ICSR 24006	60	0	96.1	151.8	5.9	31.1	6.6	6.0	0.0	3.0	2.1
71	ICSA 88006 X IESV 91131 DL	64	0	94.4	168.5	8.5	31.1	6.3	6.0	0.0	1.0	2.1
72	ICSA 91002 X ICSR 38	63	0	98.9	179.5	7.0	33.2	6.5	6.0	0.0	4.0	2.1
73	ICSA 90001 X ICSR 89058	66	0	98.2	153.3	8.9	36.7	7.5	8.0	0.0	1.0	2.1
74	ATX 623 X ICSV 95022	63	0	98.4	169	6.0	33.6	6.5	6.0	0.0	4.0	2.1
75	ICSA 276 X ICSR 24008	67	0	99.1	208.3	9.7	33.2	6.5	7.0	0.0	1.0	2.0
76	ICSA 9 X ICSR 89058	62	0	96.8	186.8	3.8	35.3	6.0	5.0	0.0	1.0	1.9
77	ICSA 44 X ICSR 172	65	0	96.3	147.7	5.1	24.5	4.6	9.0	0.0	1.0	1.9
78	ICSA 89003 X ICSR 89058	66	0	97.6	152.4	3.2	35.2	5.9	6.0	0.0	1.0	1.9
79	ICSA 687 X ICSR 162	57	0	95.9	187.5	10.6	31.3	7.0	7.0	0.0	1.0	1.9
80	ICSA 88001 X ICSR 108	65	0	99.1	196.1	5.7	33.3	6.7	6.0	0.0	1.0	1.9
81	IESA2 X ICSR 24009	65	0	94.4	156.1	4.6	29.7	6.6	6.0	0.0	1.0	1.9
82	ICSA 88006 X ICSR 162	65	0	94.8	238.4	9.3	32.7	6.1	6.0	0.0	1.0	1.8
83	ICSA 77 X ICSR 108	64	0	98.3	193.9	8.2	30.0	6.6	6.0	0.0	1.0	1.8
84	SDSA 4 X ICSR 89059	66	0	97.8	201.1	6.1	37.1	5.7	6.0	0.0	1.0	1.8
85	IS 8193	63	0	98.3	174.7	5.1	23.6	6.1	7.0	0.0	3.0	1.7
86	ICSA 89003 X ICSR 92003	66	0	98.1	204.9	4.2	32.1	5.9	6.0	0.0	1.0	1.7
87	ICSA 654 X ICSR 153	62	0	65.2	205.7	10.0	29.6	5.6	6.0	0.0	4.0	1.6
88	ICSA 90001 X ICSR 162	66	1	97.7	206.9	8.5	32.1	6.3	6.0	0.0	1.0	1.6
89	ICSA 376 X IESV 23013 DL	61	0	98.1	258.1	16.9	27.3	5.4	6.0	0.0	4.0	1.6
90	ICSA 479 X SIAYA # 66 - 2	68	2	51.6	237	5.9	21.9	6.5	8.0	1.0	1.0	1.5
91	SDSA1 X ICSR 24010	68	0	97.4	290.8	5.6	31.1	5.7	6.0	0.0	1.0	1.5
92	ICSA 366 X MACIA	60	0	98.4	177.8	5.9	28.2	5.3	6.0	0.0	4.0	1.5
93	ICSA 77 X ICSR 160	65	0	97.7	189.7	7.9	32.0	6.1	6.0	0.0	1.0	1.5
94	SDSA 4 X ICSR 24009	68	0	97	211.7	4.2	32.1	5.4	6.0	0.0	1.0	1.3
95	WAHI	63	0	99.2	132.1	4.1	28.6	6.1	6.0	0.0	1.0	1.9
96	TEGEMEO	65	0	99.6	178.7	5.7	23.4	7.2	6.0	0.0	1.0	2.8
97	MACIA (check)	65	0	99.2	279.2	3.6	21.3	7.3	7.0	0.0	4.0	2.1
	Mean	63	0	94.6	209	6.8	31.4	6.9	6.5	0	1.8	3.0
	SEm+/-	0.95	0.01	4.73	10.37	1.59	1.41	0.6	0.37	0.03	0.25	0.04
	CV(%)	2.6	34	8.6	8.6	40.5	7.7	15	9.9	28	23	21

Appendix XII. Average heterosis and heterobeltiosis for selected hybrids across dry low land and sub-humid environments

No	Hybrids	Days to 50% flowering		Productive tillers		Plant height (cm)		Panicle (cm)		Panicle length (cm)		Panicle width (cm)		Grain weight /panicle (g)	
		H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}
1	ATX623xICSV95022	-6.01**	-7.49**	15.87	12.5	19.01**	17.66*	47.33*	33.9	11.81**	6.06	16.1	-2.1	16.95	-0.48
2	ATX623xIESV91104DL	-5.38**	-6.43*	35.48	31.25	32.61**	11.81*	60.58	36.1	6.13	-2.15	21.08*	8	76.08**	38.48*
3	ATX623xIESV91131DL	-7.91**	-5.44*	20.83	-9.38	27.52**	21.49**	91.10**	65.85	10.42*	7.71	3.52	-4.13	34.66	16.6
4	ATX623xKARI-MTAMA1	-7.25**	-5.65*	61.29	56.25	-37.22**	-23.17**	87.83*	46.83	14.92	12.99	10.93	0.21	80.54**	60.05**
5	ATX623X*Macia*	-7.80**	-6.10*	45.00*	33.75*	28.57**	23.80**	76.67**	64.34	17.59**	12.67*	23.66*	18.46	28.1	18.34*
6	ATX623xMAKUENI LOCAL	-11.51**	-7.90**	95.12	60	21.53**	-4.41	90.88**	83.37*	17.99**	3.89	5.88	-11.09	16.86	7.15
7	CK60AxIESV23010DL	-6.82**	-11.48**	-8.33	-8.33	45.37**	25.42**	54.56*	14.24	20.36**	15.88*	25.85*	5.01	57.76*	28.58
8	CK60AxKARI-MTAMA1	-5.58**	-8.85**	23.08*	16.5	37.39**	14.04*	79.51**	20.84	15.09**	9.18	48.30**	20.99*	42.54	10.75
9	CK60AxSP74278	-9.96**	-10.90**	20	16.67	24.96**	8.37	28.62**	22.01**	11.17*	1.81	16.05	0.24	31.45	9.53
10	ICSA11xS35	-4.35*	-7.91**	50.00*	48.3	52.92**	34.76**	57.3.76**	54.27	15.23**	16.74*	31.55**	14.15	81.90**	77.18*
11	ICSA11xSP74279	-9.16**	-13.29**	33.33	20	12.17	2.58	46.90**	33.03*	11.69*	11.48*	7.63	-5.28	19.02	2.83
12	ICSA12xICSR93001	-6.57**	-5.23*	25	25	35.64**	27.44**	64.14*	55.81	7.21	-2.46	23.60*	20.23	31.4*	18.6
13	ICSA12xIESV23019DL	-7.48**	-2.39	61.05	50.54	58.45**	38.54**	89.30**	65.08**	-3.95	-4.73	18.94*	6.68	38.81	37
14	ICSA12xIESV91104DL	-5.26**	-2.14	70.37	43.33	44.21**	20.06**	68.62*	65.08*	-2.38	-16.54**	27.07**	16.4	30.1	8.72
15	ICSA12xKARI-MTAMA1	-4.96**	-0.98	40.74	26.67	-48.11**	-31.13**	57.22*	44.75	-3.11	-15.49**	19.29*	10.7	30.81	17.52
16	ICSA12xSIAYA46-2	-6.38**	-3.53	57.14**	125	50.22**	29.81**	76.07**	45.42	1.62	-14.93**	25.48*	17.79	24.45	18.52
17	ICSA15xICSR160	-11.50**	-7.91**	41.18	-11.11	29.95**	12.11	58.09**	42.61*	20.60**	15.75**	26.32*	13.16	33.1	21.28
18	ICSA15xIESV91104DL	-8.24**	-3.57	50	28	46.05**	16.16**	71.15*	63.58*	1.84	-10.30*	15.45	-0.6	56.26**	27.62
19	ICSA15xTEGEMEO	-10.07**	-7.52**	41.67	33.18	74.37**	-53.61**	75.62**	71.01**	11.54*	-4.58	30.85**	15.47	68.16**	57.66*
20	ICSA276xIESV91104DL	-4.93**	-3.57	93.33	89.36	-18.16**	-11.44*	34.77	-9.33	9.66*	-4.84	32.93**	31.20**	-5.34	-5.55
21	ICSA293xICSR24009	-9.46**	-6.28*	13.33	15	8.97	8.74	67.95**	53.45*	11.13*	7.58	51.56**	40.84**	79.10**	54.48*
22	ICS687xIESV23011DL	-7.58**	-7.93**	75.76**	56.52**	5.73	-7.82	14.25	-8.28	16.11**	4.26	46.69**	30.62**	39.17	17.86
23	ICSA88001xICSR160	-10.14**	-4.13	-27.27	-48.15	-26.76**	23.27**	25.9	19.43	17.96**	16.15**	37.76**	29.61**	57.33*	35.15
24	ICSA88001xICSR93034	-9.22**	-11.70**	29.00**	25.77*	36.08**	16.67**	77.09*	41.9	18.69**	13.36*	53.02**	36.94**	59.62**	23.65
25	ICSA88001xKARI-MTAMA1	-8.07**	-9.40**	92.45	93.33	41.91**	34.21**	47.13**	43.72*	20.06**	10.57*	54.73**	41.36**	72.75**	51.37*
26	ICSA88001x*Macia*	-17.53**	-13.99**	56.41	47.39	29.17**	17.91*	43.91**	42.80*	16.77**	9.27	28.67**	24.77*	15.96	5.44
27	ICSA88006xIESV91131DL	-6.86**	-3.26	48.77	26.67	32.53**	27.71**	11.64**	8.86	4.27	-2.46	0.87	-12.17	-8.09	-19.54
28	ICSA88006xKARI-MTAMA1	-5.45**	-4.2	36.36	16.67	56.80**	30.74**	25.33	-15.95	12.58**	1.92	26.72**	7.82	77.23**	58.91*
29	ICSA89003xIESV23011DL	-4.06*	-3.12	-45.83	-48	50.97**	23.98**	88.98**	67.51**	-0.08	-4.52	26.01**	1.81	43.05	7.92
30	ICSA9xICSR56	-1.9	-1.74	-65.08	-67.65	40.65**	27.99**	39.90**	22.42**	15.44**	7.18	19.72	18.26	30.66	10.37
31	ICSA90001xICSR43	-5.12**	-4.27	16.67	14.44	11.92	7.05	84.09	52.53	17.11**	17.08**	27.54**	15.14	33.04	28.59
32	ICSA90001xICSR89001	-9.90**	-6.31**	90.16	5.45	6.12	3.21	53.97**	48.74*	12.85**	12.60*	23.11**	9.53	52.49*	38.35
33	ICSA91002xICSR38	-8.96**	-9.24**	85.71	63.8	-17.02*	8.62	73.68**	45.60**	10.19*	9.02	22.60*	3.39	46.49	28.31
34	IESA2xICSR24009	-13.90**	-7.21**	52.38	-20	8.12	-7.3	76.77	38.38	9.72*	6.95	20.85*	16.31	0.99	-10.18
35	IESA2xICSR24010	-12.89**	-5.52*	33.33	20	29.38**	-2.32	69.82**	84.91*	9.41	0.88	41.14**	36.47**	47.64	44.89
36	IESA2xSIAYA42	-11.64**	-4.96	16.67	5.22	23.12**	1.88	77.52	38.76	14.91*	-1.01	9.95	-2.79	12.68	6.86
37	MA6xIESV23010DL	-3.59	-3.67	22.22	-8.33	55.26**	31.91**	40.35**	38.67*	12.11*	10.86	32.53**	7.84	37.87	7.37
38	MA6xMAKUENI LOCAL	-7.75**	-10.05**	94.59	44	34.32**	-2.05	64.39**	56.99**	24.77**	18.95**	18.84	-10.92	17.18	-6.2
39	MA6xS35	1.26	-7.35**	23.03	13.1	-55.67**	29.53**	74.50**	58.07**	8.12	6.2	23.23*	2.78	72.00*	46.85
40	SDSA1xICSR24009	-4.05*	0	60	0	24.70**	14.58*	67.70**	65.47*	9.91*	1.89	6.28	-5.8	-4.4	-17.93
41	SDSA1xICSR24010	-11.11**	-3.29	38.71	24	42.34**	13.70**	18.14*	13.43	7.42	-9.52*	15.62	-3.61	24.96	22.23
42	SDSA1xICSR43	-5.80**	-6.07*	-85.71	-88.89	31.81**	23.62**	90.00**	86.86**	7.79	4.45	21.99*	8.12	12.26	1.65
43	SDSA1xICSR93001	-9.34**	-3.05	76.47	25	50.50**	41.21**	20.47**	19.38**	6.06	-2.71	35.32**	18.86	78.05**	49.24*
44	SDSA1xIESV91104DL	-11.58**	-5.40*	60	46.67	51.07**	25.62**	65.83*	50.18*	-4.78	-17.97**	6.12	-11.6	2.83	-19.59
45	SDSA1xIESV91131DL	-7.75**	-4.23	30	25	39.24**	34.86**	65.70**	59.24**	3.16	-6.4	1.13	-12.83	12.87	-2.92
46	SDSA1xBUSIA28-1	-7.07**	-2.81	33.33	-20	42.05**	16.10**	81.96	71.3	8.78	-25.76**	17.25	0.43	42.71	32.11
47	SDSA4xICSR24009	-4.67**	0.23	-70.37	-80	37.64**	25.82**	31.76**	23.54*	14.42**	8.62	4.77	-5.8	-9.89	-20.6

Appendix XII continues

No	Hybrids	Days to 50% flowering		Productive tillers		Plant height (cm)		Panicle (cm)		Panicle length (cm)		Panicle width (cm)		Grain weight /panicle (g)	
		H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}	H_{MP}	H_{BP}
49	ATX623xICSV95022	-6.01**	-7.49**	15.87	12.5	19.01**	17.66*	47.33*	33.9	11.81**	6.06	16.1	-2.1	16.95	-0.48
50	ATX623xIESV91104DL	-5.38**	-6.43*	35.48	31.25	32.61**	11.81*	60.58	36.1	6.13	-2.15	21.08*	8	76.08**	38.48*
51	ATX623xIESV91131DL	-7.91**	-5.44*	20.83	-9.38	27.52**	21.49**	91.10**	65.85	10.42*	7.71	3.52	-4.13	34.66	16.6
52	ATX623xKARI-MTAMA1	-7.25**	-5.65*	61.29	56.25	-37.22**	-23.17**	87.83*	46.83	14.92	12.99	10.93	0.21	80.54**	60.05**
53	ATX623X*Macia*	-7.80**	-6.10*	45.00*	33.75*	28.57**	23.80**	76.67**	64.34	17.59**	12.67*	23.66*	18.46	28.1	18.34*
54	ATX623xMAKUENI LOCAL	-11.51**	-7.90**	95.12	60	21.53**	-4.41	90.88**	83.37*	17.99**	3.89	5.88	-11.09	16.86	7.15
55	CK60AxIESV23010DL	-6.82**	-11.48**	-8.33	-8.33	45.37**	25.42**	54.56*	14.24	20.36**	15.88*	25.85*	5.01	57.76*	28.58
56	CK60AxKARI-MTAMA1	-5.58**	-8.85**	23.08*	16.5	37.39**	14.04*	79.51**	20.84	15.09**	9.18	48.30**	20.99*	42.54	10.75
57	CK60AxSP74278	-9.96**	-10.90**	20	16.67	24.96**	8.37	28.62**	22.01**	11.17*	1.81	16.05	0.24	31.45	9.53
58	ICSA11xS35	-4.35*	-7.91**	50.00*	48.3	52.92**	34.76**	57.3.76**	54.27	15.23**	16.74*	31.55**	14.15	81.90**	77.18*
59	ICSA11xSP74279	-9.16**	-13.29**	33.33	20	12.17	2.58	46.90**	33.03*	11.69*	11.48*	7.63	-5.28	19.02	2.83
60	ICSA12xICSR93001	-6.57**	-5.23*	25	25	35.64**	27.44**	64.14*	55.81	7.21	-2.46	23.60*	20.23	31.4*	18.6
61	ICSA12xIESV23019DL	-7.48**	-2.39	61.05	50.54	58.45**	38.54**	89.30**	65.08**	-3.95	-4.73	18.94*	6.68	38.81	37
62	ICSA12xIESV91104DL	-5.26**	-2.14	70.37	43.33	44.21**	20.06**	68.62*	65.08*	-2.38	-16.54**	27.07**	16.4	30.1	8.72
63	ICSA12xKARI-MTAMA1	-4.96**	-0.98	40.74	26.67	-48.11**	-31.13**	57.22*	44.75	-3.11	-15.49**	19.29*	10.7	30.81	17.52
64	ICSA12xSIAYA46-2	-6.38**	-3.53	57.14**	125	50.22**	29.81**	76.07**	45.42	1.62	-14.93**	25.48*	17.79	24.45	18.52
65	ICSA15xICSR160	-11.50**	-7.91**	41.18	-11.11	29.95**	12.11	58.09**	42.61*	20.60**	15.75**	26.32*	13.16	33.1	21.28
66	ICSA15xIESV91104DL	-8.24**	-3.57	50	28	46.05**	16.16**	71.15*	63.58*	1.84	-10.30*	15.45	-0.6	56.26**	27.62
67	ICSA15xTEGEMEO	-10.07**	-7.52**	41.67	33.18	74.37**	-53.61**	75.62**	71.01**	11.54*	-4.58	30.85**	15.47	68.16**	57.66*
68	ICSA276xIESV91104DL	-4.93**	-3.57	93.33	89.36	-18.16**	-11.44*	34.77	-9.33	9.66*	-4.84	32.93**	31.20**	-5.34	-5.55
69	ICSA293xICSR24009	-9.46**	-6.28*	13.33	15	8.97	8.74	67.95**	53.45*	11.13*	7.58	51.56**	40.84**	79.10**	54.48*
70	ICS687xIESV23011DL	-7.58**	-7.93**	75.76**	56.52**	5.73	-7.82	14.25	-8.28	16.11**	4.26	46.69**	30.62**	39.17	17.86
71	ICSA88001xICSR160	-10.14**	-4.13	-27.27	-48.15	-26.76**	23.27**	25.9	19.43	17.96**	16.15**	37.76**	29.61**	57.33*	35.15
72	ICSA88001xICSR93034	-9.22**	-11.70**	29.00**	25.77*	36.08**	16.67**	77.09*	41.9	18.69**	13.36*	53.02**	36.94**	59.62**	23.65
73	ICSA88001xKARI-MTAMA1	-8.07**	-9.40**	92.45	93.33	41.91**	34.21**	47.13**	43.72*	20.06**	10.57*	54.73**	41.36**	72.75**	51.37*
74	ICSA88001x*Macia*	-17.53**	-13.99**	56.41	47.39	29.17**	17.91*	43.91**	42.80*	16.77**	9.27	28.67**	24.77*	15.96	5.44
75	ICSA88006xIESV91131DL	-6.86**	-3.26	48.77	26.67	32.53**	27.71**	11.64**	8.86	4.27	-2.46	0.87	-12.17	-8.09	-19.54
76	ICSA88006xKARI-MTAMA1	-5.45**	-4.2	36.36	16.67	56.80**	30.74**	25.33	-15.95	12.58**	1.92	26.72**	7.82	77.23**	58.91*
77	ICSA89003xIESV23011DL	-4.06*	-3.12	-45.83	-48	50.97**	23.98**	88.98**	67.51**	-0.08	-4.52	26.01**	1.81	43.05	7.92
78	ICSA9xICSR56	-1.9	-1.74	-65.08	-67.65	40.65**	27.99**	39.90**	22.42**	15.44**	7.18	19.72	18.26	30.66	10.37
79	ICSA90001xICSR43	-5.12**	-4.27	16.67	14.44	11.92	7.05	84.09	52.53	17.11**	17.08**	27.54**	15.14	33.04	28.59
80	ICSA90001xICSR89001	-9.90**	-6.31**	90.16	5.45	6.12	3.21	53.97**	48.74*	12.85**	12.60*	23.11**	9.53	52.49*	38.35
81	ICSA91002xICSR38	-8.96**	-9.24**	85.71	63.8	-17.02*	8.62	73.68**	45.60**	10.19*	9.02	22.60*	3.39	46.49	28.31
82	IESA2xICSR24009	-13.90**	-7.21**	52.38	-20	8.12	-7.3	76.77	38.38	9.72*	6.95	20.85*	16.31	0.99	-10.18
83	IESA2xICSR24010	-12.89**	-5.52*	33.33	20	29.38**	-2.32	69.82**	84.91*	9.41	0.88	41.14**	36.47**	47.64	44.89
84	IESA2xSIAYA42	-11.64**	-4.96	16.67	5.22	23.12**	1.88	77.52	38.76	14.91*	-1.01	9.95	-2.79	12.68	6.86
85	MA6xIESV23010DL	-3.59	-3.67	22.22	-8.33	55.26**	31.91**	40.35**	38.67*	12.11*	10.86	32.53**	7.84	37.87	7.37
86	MA6xMAKUENI LOCAL	-7.75**	-10.05**	94.59	44	34.32**	-2.05	64.39**	56.99**	24.77**	18.95**	18.84	-10.92	17.18	-6.2
87	MA6xS35	1.26	-7.35**	23.03	13.1	-55.67**	29.53**	74.50**	58.07**	8.12	6.2	23.23*	2.78	72.00*	46.85
88	SDSA1xICSR24009	-4.05*	0	60	0	24.70**	14.58*	67.70**	65.47*	9.91*	1.89	6.28	-5.8	-4.4	-17.93
89	SDSA1xICSR24010	-11.11**	-3.29	38.71	24	42.34**	13.70**	18.14*	13.43	7.42	-9.52*	15.62	-3.61	24.96	22.23
90	SDSA1xICSR43	-5.80**	-6.07*	-85.71	-88.89	31.81**	23.62**	90.00**	86.86**	7.79	4.45	21.99*	8.12	12.26	1.65
91	SDSA1xICSR93001	-9.34**	-3.05	76.47	25	50.50**	41.21**	20.47**	19.38**	6.06	-2.71	35.32**	18.86	78.05**	49.24*
92	SDSA1xIESV91104DL	-11.58**	-5.40*	60	46.67	51.07**	25.62**	65.83*	50.18*	-4.78	-17.97**	6.12	-11.6	2.83	-19.59
93	SDSA1xIESV91131DL	-7.75**	-4.23	30	25	39.24**	34.86**	65.70**	59.24**	3.16	-6.4	1.13	-12.83	12.87	-2.92
94	SDSA1xBUSIA28-1	-7.07**	-2.81	33.33	-20	42.05**	16.10**	81.96	71.3	8.78	-25.76**	17.25	0.43	42.71	32.11
95	SDSA4xICSR24009	-4.67**	0.23	-70.37	-80	37.64**	25.82**	31.76**	23.54*	14.42**	8.62	4.77	-5.8	-9.89	-20.6
96	SDSA4xICSR43	-6.40**	-3.82	-62.5	-66.67	30.91**	22.13**	88.41**	64.74**	17.73**	16.97**	34.19**	20.65	28.75	19.88

Note: * significant at 5% : H_{MP} = Heterosis over mid parent; H_{BP}= Heterosis over better parent

Appendix XIII. Heterobeltiosis for days to 50% flowering, plant height, panicle length and yield for sorghum hybrids within locations

		Days to flowering			Mature plant height			Panicle length			Grain yield		
	CROSS	**KBK**	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**
1	A_2DN_{55}xAIHR91075	-3.05	-5.51**	-6.52	67.65**	59.90**	32.57**	24.41**	8.49	14.65	24.25**	79.27	16.05
2	ATX623xGADAM	-13.67**	-10.00**	-2.21	69.26**	41.45**	29.45**	17.41**	-4.72	-14.48**	81.94**	90.10*	45.69
3	ATX623xICSR23019	-5.04*	-0.77	-1.47	100.24**	57.20**	41.13**	27.41**	10.24	-3.09	77.82**	204.38**	34.65
4	ATX623xICSV95022	-7.64**	-4.55*	-10.14**	16.05*	10.94	8.71	17.07**	-2.76	4.55	41.87*	-27.01	-5.7
5	ATX623xIESV91104DL	-5.71**	-4.62*	-9.87**	29.71**	25.57**	-22.02**	2.22	-6.99	-0.97	57.07**	19.73	36.34
6	ATX623xIESV91131DL	-7.91**	-3.08	-5.19	42.56**	15.78	7.76	21.48**	5.85	-4.44	32.22*	6.32	22.51
7	ATX623xIESV91136DL	-7.91**	-3.08	0.74	40.13**	29.99**	6.73	25.19**	12.36	4.05	85.00**	63.07	-4.75
8	ATX623xKARI-MTAMA1	-7.91**	-6.92**	-4.93	-41.86**	-12.32	16.11*	4.81	-9.59	-3.28	47.15**	120.66**	0.69
9	ATX623x*MACIA*	-9.09**	-8.15**	-3.68	36.55**	25.54**	7.36	23.33**	6.18	9.27	10.42	1.97	27.56
10	ATX623xMAKUENI LOCAL	-11.51**	-9.23**	-2.94	10.02*	-10.51*	-11.48**	10.00*	1.79	0	-7.53	-3.92	31.99
11	CK60AxIESV23010DL	-6.82**	-8.80**	-18.52**	19.70**	29.69**	27.71**	12.57**	23.91**	9.24	15.3	57.33	25.02
12	CK60AxKARI-MTAMA1	-7.30**	-11.72**	-7.75*	12.05*	12.67	18.52**	18.14**	7.66	1.74	-5.57	36.02	-6.7
13	CK60AxSP74278	-12.23**	-2.4	-17.33**	9.81	11.31	2.86	6.55	9.91	-13.18*	-16.79	52.5	17.43
14	CK60AxR8602	-6.06**	-4.80*	-8.15*	52.66**	25.69*	19.36*	35.24**	23.32**	37.94**	76.03*	16.65	50.24
15	ICSA11xICSR172	-4.51*	-2.36	2.27	28.97**	24.79*	21.77**	6.47	-7.47	17.31*	102.21**	55.97	55.17
16	ICSA11xS35	-9.02**	-7.87**	-6.82*	38.79**	40.49**	-22.59**	9.71*	-1.62	15.14*	70.05**	85.36**	47.52*
17	ICSA11xSP74279	-11.43**	-5.51**	-22.82**	3.8	1.94	1.87	17.27**	14.45*	-12.13*	-17.64	21.4	59.96
18	ICSA12xICSR162	-9.66**	1.57	2.21	87.49**	70.67**	49.69**	-2.26	-9.78	-8.47	20.94	110.73**	115.91**

Appendix XIII continues

		Days to flowering			Mature plant height			Panicle length			Grain yield		
	CROSS	KBK	MWL	UKIR	KBK	MWL	UKIR	KBK	MWL	UKIR	KBK	MWL	UKIR
19	ICSA12xICSR172	-11.72**	-3.15	-0.74	23.38**	21.40*	21.43**	-4.37	-4.89	-18.47**	19.69	78.90*	64.89
20	ICSA12xICSR93001	-6.90**	-3.76*	-5.56	28.72**	31.78**	20.34**	0.45	-3.26	-4.75	23.57	-18.6	76.43*
21	ICSA12xIESV23019DL	-8.72**	-3.13	4.93	49.05**	40.60**	25.20**	-3.12	-16.85**	1.53	17.15	26.26	80.50*
22	ICSA12xIESV91104DL	-6.90**	-1.56	-1.32	34.78**	24.43**	0.05	-4.68	-29.76**	-13.39**	32.12*	-34.13	105.71**
23	ICSA12xIESV92156	-10.34**	3.15	-0.74	38.50**	35.72**	18.75*	2.56	-13.59*	-1.86	3.16	15.65	90.79*
24	ICSA12xIESV92158DL	-8.97**	0	3.68	36.19**	30.58**	19.11*	-1.06	-17.66**	-11.53*	5.85	-0.89	50.63
25	ICSA12xIESV92172DL	-10.34**	-4.72*	-0.74	33.66**	33.08**	24.55**	9.50**	-16.85**	-8.47	29.89	4.92	53.54
26	ICSA12xKARI-MTAMA1	-7.59**	-2.34	2.11	-50.59**	25.98**	14.71*	-14.33**	39.57**	-11.69*	14.29	34.49	-1.71
27	ICSA12xSIAYA46-2	-8.97**	-1.52	-5.13	47.24**	41.16**	-0.23	-7.69*	-17.39**	-20.00**	21.43	22.64	-18.75
28	ICSA15xICSR160	-14.19**	-7.75**	-3.5	16.44*	8.71	11.81	11.61**	16.43**	12.50*	16.16	35.71	-18.31
29	ICSA15xICSR162	-2.88	1.56	-3.5	106.59**	46.95**	85.87**	2.38	7.02	29.57**	46.91*	26.1	81.84*
30	ICSA15xICSR172	-9.35**	-7.03**	3.5	39.09**	77.52**	28.56**	-4.17	-7.72	7.45	23.84	22.05	4.52
31	ICSA15xIESV91104DL	-8.57**	-3.13	0.66	18.57**	31.74**	-3.81	-12.20**	-15.17**	-0.21	79.67	40.79*	4.7
32	ICSA15xTEGEMEO	-10.07**	-6.67**	-9.09*	61.15**	71.99**	24.00**	-8.48**	-8.15	6.38	122.11*	44.38	34.66
33	ICSA276xICSR162	-8.33**	-5.07**	12.12**	56.76**	37.54**	13.41*	-4.1	-5.47	-7.57	15.07	56.07	-53.80**
34	ICSA276xICSR24008	-5.56**	-2.9	6.06	13.46*	3.38	-11.3	-2.69	0.91	-0.18	9.12	-13.42	-42.13**
35	ICSA276xIESV91104DL	-6.25**	-4.35*	-9.21**	-20.03**	-22.51**	-9.83*	0.42	-1.22	-15.86**	18.97	-27.16	-55.00**
36	ICSA293xICSR24009	-11.26**	-4.96**	-6.25	23.42**	-13.88	18.78**	24.27**	-4.98	3.07	39.02**	82.70**	70.86*
37	ICSA366xKARI-MTAMA1	-6.57**	-7.81**	-1.41	29.69**	17.14*	16.62**	24.47**	6.02	0.65	14.75	-12.26	-31.84
38	ICSA366xMACIA	-13.99**	-11.11**	0	34.64**	38.19**	25.69**	27.24**	5.91	3.07	47.49**	-25.92	148.74**

Appendix XIII continues

		Days to 50% flowering			Mature plant height			Panicle length			Grain yield		
No.	CROSS	KBK	MWL	UKIR	KBK	MWL	UKIR	KBK	MWL	UKIR	KBK	MWL	UKIR
39	ICSA371xMACIA	-12.59**	-10.37**	-4.17	59.06**	56.33**	15.49*	21.64**	5.73	2.63	40.85*	2.63	37.94
40	ICSA376xIESV23013DL	-3.82	-4.65*	-8.90*	46.84**	41.67**	29.27**	23.77**	2.86	-0.83	95.03**	28.51	-20.89
41	ICSA44xIESV91104DL	-5.71**	-3.91*	-5.26	24.22**	15.68*	1.07	2.78	1.43	23.02**	25.79	14.34	44.33
42	ICSA44xMAKUENI LOCAL	-13.67**	-1.57	2.27	17.57**	-10.18*	-5.57	36.16**	22.42**	32.13**	14.83	57.56	101.94*
43	ICSA479xSIAYA66-1	-3.52	3.03	5.8	9.06	6.34	1.43	19.95**	4.22	16.07	33.41	-30.82	25.00**
44	ICSA6xICSR93034	-4.83*	-4.72*	-2.72	9.96*	-21.18**	-16.68**	28.32**	13.51	13.09*	26.75*	-39.71*	1.33
45	ICSA6xIESV23011DL	-7.80**	-3.08	-4.83	25.25**	27.15**	-0.06	0.91	2.83	-17.96**	25.08	12.7	46.78
46	ICSA654xICSR153	-11.35**	-10.00**	-7.97*	16.26*	25.91**	-3.56	6.58	-0.81	-24.60**	10.74	30.95	3.59
47	ICS687xICSR162	-7.35**	-8.80**	-8.15*	31.26**	34.84**	14.20*	22.56**	26.83**	21.61**	57.67*	33.53	-8.69
48	ICS687xIESV23011DL	-9.22**	-6.92**	-7.59*	2.71	-13.48*	-12.07*	7.25*	19.33**	-13.59**	12.52	10.3	-6.62
49	ICSA77xICSR160	-11.49**	-9.15**	-6.43	18.36**	-0.64	-1.92	6.1	4.09	-9.52	10.07	-28.27	-26.98
50	ICSA88001xICSR108	-12.84**	-0.76	-7.69*	31.67**	19.11*	3.88	38.92**	-3.77	-9.86*	37.82*	54.47	-18.75
51	ICSA88001xICSR160	-10.14**	-6.34**	-2.56	22.69**	8.29	42.33**	20.00**	11.59*	-0.53	34.42*	60.07*	-9.21
52	ICSA88001xICSR93034	-10.14**	-8.33**	-16.03**	29.48**	17.00**	1.92	34.87**	-5.22	12.68*	58.90**	-29.22	59.99*
53	ICSA88001xKARI-MTAMA1	-11.49**	-1.52	-14.10**	47.98**	17.24*	42.24**	32.93**	-0.58	4.4	74.85**	29.58	66.33**
54	ICSA88001xMACIA	-18.92**	-4.44*	-19.23**	16.48*	28.75**	6.03	25.37**	1.74	-3.52	12.52	-15.23	11.72
55	ICSA88006xICSR162	-3.62	-3.70*	-5.77	96.95**	111.42**	67.15**	10.10**	-0.31	0.53	63.74**	9.53	-37.29
56	ICSA88006xIESV91131DL	-7.19**	-5.19**	1.28	34.33**	20.73*	28.57**	3.26	-3.74	-7.18	-13.13	-13.5	-30.36

Appendix XIII continues

No.	CROSS	Days to 50% flowering			Mature plant height			Panicle length			Grain yield		
		KBK	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**
57	ICSA88006xKARI-MTAMA1	-5.80**	-3.70*	-3.21	42.46**	23.57**	26.87**	-1.95	15.26*	-8.93	43.96**	74.95**	126.98**
58	ICSA89003xICSR89058	2.31	3.94*	1.41	62.39**	15.8	43.47**	26.99**	20.83**	8.66	150.06**	32.45	69.9
59	ICSA89003xICSR92003	2.31	4.72*	-4.23	59.74**	40.82**	51.23**	13.07**	7.4	7	123.00**	16.87	80.5
60	ICSA89003xIESV23011DL	-7.80**	-1.54	0	45.18**	21.49**	4.52	2.42	-3.67	-12.78**	5.85	-10.16	35.94
61	ICSA 89004xICSR89028	-15.03**	-8.51**	7.53*	4.89	-3.91	15.84*	-2.41	20.70**	11.52*	11.24	-14.6	-49.50**
62	ICSA9xICSR56	-2.27	-3.82*	-0.7	24.25**	18.27*	47.92**	5.38	-2.74	23.49**	50.75*	-18.17	8.79
63	ICSA9xICSR89058	-5.30*	-3.82*	13.64**	46.00**	32.19**	67.28**	18.99**	11.61	28.19**	90.60**	31.95	28.34
64	ICSA90001xICSR162	-6.21**	-3.62*	-7.89*	51.42**	50.25**	15.80*	13.56**	-17.90**	6.8	8.68	-7.13	38.15
65	ICSA90001xICSR172	0	-7.25**	-12.50**	19.66*	-4	-0.3	18.98**	-14.67**	10.8	54.66**	25.13	45.04
66	ICSA90001xICSR24008	-1.38	-2.9	-3.29	41.32**	24.21*	14.89*	23.39**	46.33**	29.80**	57.34**	22.54	86.00**
67	ICSA90001xICSR43	-6.08**	-5.76**	-1.27	5.2	9.7	6.05	22.13**	1.35	0.47	-1	46.02	13.53
68	ICSA90001xICSR89001	-10.81**	-2.16	-5.73	15.66*	5.26	-12.32	12.74**	-0.67	2.5	32.99*	109.44**	-13.5
69	ICSA90001xICSR89058	-6.21**	-3.62*	-6.58*	19.36*	8.56	2.42	21.36**	0.94	24.60**	1.63	-4.73	36.51
70	ICSA90001xICSR92003	-4.14*	-6.52**	1.97	30.22**	27.02**	25.25**	16.61**	-7.67	26.60**	28.18	37.94**	13.53
71	ICSA91002xICSR38	-11.19**	-8.76**	-7.75*	19.85**	11.81	-10.05	18.15**	8.53	-10.71	44.21*	25.02	-14.07
72	IESA2xICSR24007	-15.28**	-3.1	-4.86	23.35**	24.86*	14.57	8.46*	0.97	-5.24	25.68	14.88	-52.15**
73	IESA2xICSR24008	-6.94**	-6.98**	-5.56	24.73**	114.17**	29.09**	34.93**	1.61	26.67**	103.44**	37.58	-0.76
74	IESA2xICSR24009	-15.89**	-6.38**	-2.78	-3.48	-16.54*	1.37	15.50**	-8.24	17.81**	9.49	-29.4	-41.57*
75	IESA2xICSR24010	-13.19**	-12.59**	0	18.73**	-18.01**	-4.02	-2.94	-2.42	8.14	40.48	91.28*	-16.69
76	IESA2xSIAYA42	-12.84**	-10.22**	4.17	6.29	-0.33	-0.39	0.74	-12.42	13.57*	-0.3	-17.76	-10.75

Appendix XIII continues

No.	CROSS	Days to 50% flowering			Mature plant height			Panicle length			Grain yield		
		KBK	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**	**KBK**	**MWL**	**UKIR**
77	MA6xIESV23010DL	-8.33**	-5.60**	-6.57	26.09**	41.53**	27.22**	13.14**	11.55	1.15	-4.3	10.08	26.61
78	MA6xMAKUENI LOCAL	-14.39**	-10.24**	-8.76*	11.94*	-6.64	-10.62*	11.24**	12.3	32.32**	-27.95	-6.57	27.08
79	MA6xS35	0.83	-8.80**	-13.87**	36.16**	33.73**	16.37**	7.81	7.41	-2.42	105.77**	21.52	47.25
80	SDSA1xICSR24009	-5.96**	-6.38**	11.43**	21.77**	-0.38	27.02**	4.04	1.56	0	-14.45	-21.6	6.87
81	SDSA1xICSR24010	-11.72**	-4.90**	5.71	24.45**	12.70*	3.34	-5.9	-10.64	-12.09**	29.87	1.76	23.21
82	SDSA1xICSR43	-6.76**	-7.80**	-5.06	16.96*	31.11**	22.33**	6.52	8.09	-6.62	-34.60*	68.06	-4.87
83	SDSA1xICSR93001	-9.66**	-5.67**	3.47	54.11**	32.20**	38.20**	3.11	1.28	-13.58**	49.08**	33.55	58.78*
84	SDSA1xIESV91104DL	-13.10**	-9.93**	-1.32	20.82**	34.66**	20.41**	-11.80**	-24.40**	-17.05**	12.61	-54.38**	23.82
85	SDSA1xIESV91131DL	-9.66**	-10.64**	-1.95	45.42**	36.08**	23.10**	0.93	-7.23	-13.25**	0.53	10.04	-0.23
86	SDSA1xBUSIA28-1	-9.21**	-7.80**	5	25.22**	12.72*	11.25*	-22.98**	-38.01**	-14.40**	37.40*	19.57	16.87
87	SDSA4xICSR24009	-5.30**	-2.84	9.42*	32.53**	11.21	38.67**	7.61*	0.15	21.30**	-1.65	-55.40*	-1.47
88	SDSA4xICSR43	-6.71**	-6.38**	-0.63	23.78**	26.41**	15.65*	5.07	24.35**	-3.31	1.37	92.51*	-6.2
89	SDSA4xICSR89059	-9.40**	-4.26*	15.91**	46.09**	39.41**	39.91**	9.30**	11.18	29.21**	32.64	36.62	16.41

Note: *, ** significant at 5% and 1% level respectively; KBK = Kiboko; MWL = Miwaleni; UKIR = Ukiriguru

Appendix XIV. Estimates of general combining ability (GCA) effects of some parents for eleven traits evaluated in grain sorghum during 2011/2012 growing seasons

No.	**Parent**	**Days to 50% Flowering**	**Productive tillers**	**Mature Plant height (cm)**	**Panicle (cm)**	**Panicle Length (cm)**	**Panicle Width (cm)**	**Grain color**	**Grain weight /panicle (g)**	**Grain yield (t/ha)**
Female parents										
1	BTX623	-1.63**	-0.01	1.94*	-0.17	-0.39**	-0.24**	-0.02	10.31**	104.35**
2	CK 60B	-5.43**	0.56**	-15.42**	3.72**	-2.48**	-0.59**	0.46**	5.01**	109.65**
3	ICSB 11	-4.52**	0.25**	-14.72**	1.43**	-1.75**	-1.40**	0.09**	0.74	82.10**
4	ICSB 12	0.70**	0.04	11.06**	-0.21	-0.06	-0.23**	-0.10**	6.27**	79.40**
5	ICSB 15	-0.03	0.1	13.98**	-0.16	1.27**	-0.34**	-0.22**	10.85**	379.47**
6	ICSB 276	2.14**	0.23**	21.39**	3.93**	0.60**	1.08**	-0.13**	0.42	-137.43**
7	ICSB 293	1.20**	0.18**	-21.33**	6.17**	1.74**	1.40**	-0.02	28.62**	276.69**
8	ICSB 366	-2.55**	-0.65**	-4.66**	-1.64**	-2.23**	-0.32**	0.15**	-3.57*	-184.01**
9	ICSB 371	-3.88**	-0.41**	-9.60**	0.3	-2.01**	-0.89**	0.86**	-3.06*	56.99*
10	ICSB 376	-2.30**	0.11	43.90**	9.62**	-1.69**	0.53**	0.65**	-11.68**	-70.61*
11	ICSB 44	-0.13	-0.36**	12.07**	0.16	-3.71**	0.61**	0.20**	9.93**	64.99*
12	ICSB 479	3.87**	1.83**	-0.62	-7.08**	-8.99**	-1.22**	-0.32**	-17.23**	-485.54**
13	ICSB 6	0.42**	0.34**	15.54**	-0.64**	0.92**	1.04**	-0.08**	15.62**	136.94**
14	ICSB 654	-2.97**	2.44**	-14.90**	3.37**	-1.64**	-1.45**	0.65**	-18.26**	-187.64**
15	ICSB 687	-3.72**	1.88**	-15.81**	-2.53**	1.54**	2.58**	0.40**	-3.20*	101.50**
16	ICSB77	0.03	-0.04	-21.63**	0.92**	-0.71**	0.19**	0.09**	-12.68**	-231.19**
17	ICSB 88001	-0.07	-0.09	15.19**	-2.38**	2.38**	1.60**	-0.29**	9.94**	-27.11
18	ICSB 88006	2.70**	0.02	7.81**	0.68**	0.54**	-0.87**	-0.24**	-0.35	-131.29**
19	ICSB 89003	1.48**	-0.21**	2.81**	1.83**	1.49**	-0.03	0.31**	-8.47**	-63.86*
20	ICSB 89004	3.37**	-0.49**	-42.50**	-3.17**	3.22**	1.13**	-0.02	9.32**	264.16**
21	ICSB 9	0.45**	-0.56**	-8.67**	3.16**	1.77**	-1.37**	-0.35**	-17.97**	-152.12**
22	ICSB 90001	3.44**	-0.25**	-29.61**	-3.70**	3.32**	1.16**	-0.21**	0.85	-129.33**
23	ICSB 91002	-2.13**	-0.51**	-43.25**	1.77**	-0.39**	-0.09	0.81**	-6.91**	-21.72
24	IESB 2	-0.33*	-0.16*	-22.22**	-5.18**	-2.01**	0.64**	0.35**	-11.45**	-136.09**
25	MB 6	-6.08**	0.24**	24.11**	9.67**	-3.80**	-0.65**	0.31**	-11.32**	193.16**
26	SDSB 1	3.06**	-0.38**	20.86**	-0.72**	-0.26*	-1.13**	-0.19**	-6.28**	-23.2
27	SDSB 4	5.26**	-0.81**	-3.88**	-2.92**	4.94**	-0.95**	-0.46**	-14.05**	-211.34**
28	ICSB73	-1.30**	-0.2**	2.81**	2.08**	-0.22*	0.03**	-0.11	-7.21*	-76.08

Appendix XIV continues

No.	Parent	Days to 50% Flowering	Productive tillers	Mature Plant height (cm)	Panicle (cm)	Panicle Length (cm)	Panicle Width (cm)	Grain color	Grain weight /panicle (g)	Grain yield (t/ha)
Male parents										
1	AIHR91075	-3.30**	-0.79**	-23.87**	4.08**	-3.53**	-1.05**	-0.35**	-10.44**	-101.36**
2	GADAM	-4.80**	-0.16	6.57**	-0.32	-2.49**	-0.25**	0.65**	13.41**	347.29**
3	ICSR 108	0.45*	-0.21*	-17.80**	0.78**	0.38*	0.70**	-0.02	-13.89**	-116.12**
4	ICSR 153	-2.97**	2.44**	-14.90**	3.37**	-1.64**	-1.45**	0.65**	-18.26**	-187.64**
5	ICSR 160	0.98**	-0.41**	-8.89**	-1.67**	2.61**	0.49**	-0.19**	-0.26	-76.89*
6	ICSR 162	0.58**	-0.07	17.59**	0.70*	1.22**	0.31**	-0.12**	2.26	-37.22
7	ICSR 172	-0.07	-0.22**	-34.11**	-0.71*	-1.38**	-1.19**	-0.02	-1.97	-12.7
8	ICSR 196	1.37**	0.28**	-18.33**	0.45	-0.33	-0.24**	-0.02	-5.38**	-119.62**
9	ICSR 23019	-0.13	-0.52**	32.27**	-0.78**	0.92**	0.43**	0.31**	23.89**	326.92**
10	ICSR 24007	-1.97**	-0.09	-55.37**	-3.35**	-3.31**	-0.54**	-0.35**	-27.18**	-342.02**
11	ICSR 24008	2.03**	-0.32**	-14.88**	-2.23**	2.43**	1.78**	0.37**	-0.73	-149.70**
12	ICSR 24009	3.32**	-0.34**	-18.67**	-1.26**	1.90**	-0.55**	-0.31**	-8.45**	-258.33**
13	ICSR 24010	1.20**	-0.19*	39.65**	0.1	-2.17**	0.96**	-0.35**	-7.90**	-317.22**
14	ICSR 38	-2.13**	-0.51**	-43.25**	1.77**	-0.39*	-0.09	0.81**	-6.91**	-21.72
15	ICSR 43	4.70**	-0.77**	-15.54**	-1.78**	5.11**	0.18*	-0.35**	-7.24**	1.51
16	ICSR 56	0.03	-0.59**	-2.93*	5.48**	0.14	-1.49**	-0.35**	-16.89**	-108.97**
17	ICSR 89001	3.37**	0.01	-50.17**	-2.70**	4.19**	1.05**	-0.35**	18.59**	-331.91**
18	ICSR 89028	3.37**	-0.49**	-42.50**	-3.17**	3.22**	1.13**	-0.02	9.32**	264.16**
19	ICSR 89058	1.87**	-0.54**	-26.13**	-1.48**	3.94**	-0.14	-0.24**	-15.17**	-209.00**
20	ICSR 89059	4.53**	-0.76**	-7.90**	-4.50**	5.44**	-0.84**	-0.35**	-13.01**	-59.94
21	ICSR 92003	2.78**	-0.16	-13.67**	-1.70**	2.11**	0.59**	-0.35**	-3.47	-125.57**
22	ICSR 93001	1.70**	-0.26**	9.05**	-0.93**	1.79**	0.05	-0.35**	19.87**	61.33
23	ICSR 93034	-0.38	0.68**	28.21**	-3.14**	2.17**	1.60**	-0.35**	16.56**	107.41**
24	ICSV 95022	-2.13**	0.18*	-31.77**	-2.10**	2.76**	0.60**	0.31**	-7.16**	-56.09
25	IESV 23010 DL	-6.47**	-0.22**	7.88**	4.69**	-3.08**	-0.58**	0.65**	-1.69	123.05**
26	IESV 23011DL	-0.41*	1.54**	18.15**	1.71**	0.61**	1.86**	0.87**	9.46**	240.62**
27	IESV 23013 DL	-2.30**	0.11	43.90**	9.62**	-1.69**	0.53**	0.65**	-11.68**	-70.61*
28	IESV 23019 DL	2.20**	0.44**	51.00**	1.78**	1.37**	0.60**	0.65**	4.57*	86.33*
29	IESV 91104 DL	1.14**	-0.02	8.11**	-1.34**	-2.66**	0.57**	-0.35**	20.81**	364.48**
30	IESV 91136 DL	1.98**	-0.17*	-25.31**	0.21	-0.14	-1.80**	-0.30**	-11.14**	16.4

Appendix XIV continues

Parent		Days to 50% Flowering	Productive tillers	Mature Plant height (cm)	Panicle (cm)	Panicle Length (cm)	Panicle Width (cm)	Grain color	Grain weight /panicle (g)	Grain yield (t/ha)
31	IESV91131DL	-0.80**	-0.29**	-20.83**	2.28**	1.56**	-0.82**	0.35**	1.16	280.53**
32	IESV92156	0.03	0.19*	-18.23**	-0.12	1.37**	-0.47**	-0.35**	-1.94	83.39*
33	IESV92158DL	0.70**	1.18**	-21.60**	-0.80**	-0.48**	-0.84**	-0.35**	-7.99**	170.53**
34	IESV92172 DL	-1.63**	-0.01	-19.50**	4.85**	1.09**	-0.99**	-0.35**	-2.49	179.08**
35	KARI MTAMA 1	-0.66**	-0.1	22.55**	-1.12**	-1.43**	0.52**	-0.30**	19.21**	107.87**
36	*Macia*	-3.15**	0.01	-17.39**	-0.53	-0.11	-0.33**	0.28**	-5.86**	-65.71
37	MAKUENI LOCAL	-4.24**	0.11	39.36**	5.02**	-1.55**	0.68**	0.65**	-8.81**	-150.19**
38	S35	-6.47**	0.93**	23.97**	6.38**	-3.66**	-0.93**	-0.35**	6.49**	438.43**
39	SIAYA # 66 – 2	3.87**	1.83**	-0.62	-7.08**	-8.99**	-1.22**	-0.32**	-17.23**	-485.54**
40	SIAYA #46-2	2.37**	-0.06	42.17**	-4.10**	-2.01**	-0.55**	0.81**	-1.19	-131.74**
41	SIAYA#42	1.03**	0.31**	-17.57**	-8.27**	-4.08**	-1.17**	1.65**	-14.49**	-45.37
42	SP 74278	-4.63**	0.38**	-25.30**	9.65**	-3.09**	-1.67**	0.65**	-11.19**	191.09**
43	SP 74279	-6.13**	0.04	-37.13**	3.40**	-0.59**	-2.14**	0.31**	-17.61**	-477.22**
44	TEGEMEO	-2.47**	0.41**	43.20**	2.62**	-0.73**	0.36**	-0.19**	22.72**	743.06**
45	BUSIA #28-1	3.20**	-0.29**	47.53**	-4.88**	-6.04**	-0.90**	0.81**	-1.59	243.74**
46	R8602	-4.80**	0.94**	-42.07**	1.60**	-1.09**	-1.09**	0.25**	-17.69**	-297.31**

Note *, ** significant at 5% level and 1% respectively

Appendix XV. Comparison of General combining ability (GCA) Effects for some traits evaluated in sorghum at Kiboko, Miwaleni and Ukiriguru during 2010-2012 seasons

		Days to 50% flowering			Plant height (cm)			Panicle length (cm)			Panicle width (cm)			Yield (t/ha)		
No	**Parent**	**KBK**	**MIW**	**UKR**	**KBK**	**MIW**	**UKR**	**KBK**	**MIW**	**UKR**	**KBK**	**MIW**	**UKR**	**KBK**	**MIW**	**UKR**
	Female parents															
1	BTX 623	-1.00**	-1.44**	-2.46**	6.79**	2.43	-3.41**	-0.54**	-0.3	-0.34	-0.67**	0.02	-0.07	37.43**	171.68*	103.93**
2	CK 60B	-3.11**	-4.67**	-8.50**	-16.34**	-18.57**	-11.34**	-3.32**	-1.23**	-2.89**	-1.53**	0	-0.25*	-85.40**	107.80**	-43.43*
3	ICSB11	-3.11**	-3.00**	-7.46**	-20.23**	-12.05**	-11.88**	-1.67**	-0.52	-3.07**	-2.25**	-0.30**	-1.66**	-59.31**	96.13**	-60.51**
4	ICSB 12	1.04**	0.03	1.02**	17.62**	12.95**	2.60*	-0.04	-0.57*	0.45*	-0.72**	0.14	-0.1	14.08	87.80*	16.32
5	ICSB15	-1.01**	-0.17	1.07**	9.81**	26.18**	5.95**	0.3	3.19**	0.31	-0.71**	0.74**	-1.06**	52.78	77.80**	42.82*
6	ICSB 276	2.06**	3.00**	1.37**	29.90**	35.55**	-1.28	2.03**	0.4	-0.62**	2.63**	-0.1	0.72**	73.76**	-100.54**	-85.5**
7	ICSB293	1.89**	3.83**	-2.13**	-6.17**	-51.52**	-6.31**	5.83**	-1.32**	0.71**	4.75**	-1.18**	0.62**	139.31**	-267.20**	197.8*
8	ICSB 366	-2.36**	-3.67**	-1.63**	-7.62**	-0.37	-5.99**	-0.77**	-3.02**	-2.89**	0.2	-0.83**	-0.33**	17.36	-217.20**	-152.18**
9	ICSB 371	-2.61**	-2.67**	-6.38**	-1.87	-0.42	-26.51**	0.03	-3.27**	-2.79**	-0.45**	-0.78**	-1.43**	27.86**	82.8	60.32**
10	ICSB 376	-2.11**	-1.67**	-3.13**	51.83**	56.98**	22.89**	0.23	-3.07**	-2.24**	1.15**	-1.28**	1.72**	7.56	-117.20**	97.82**
11	ICSB 44	-1.44**	-0.33	1.37**	15.20**	2.45	18.56**	-4.61**	-5.15**	-1.39**	-0.09	0.18	1.74**	-18.98	-17.2	31.16**
12	ICSB 479	3.39**	4.83**	3.37**	-12.27**	21.38**	-10.96**	-9.42**	-10.8**	-6.69**	-2.20**	-0.53**	-0.93**	-87.24**	-117.20**	-252.18**
13	ICSB 6	1.73**	-0.50**	0.04	21.38**	12.02**	13.22**	0.99**	0.47	1.31**	1.51**	0.93**	0.67**	113.52**	399.46**	-102.18**
14	ICSB 654	-2.61**	-0.17	-6.13**	-20.27**	3.18	-27.61**	1.43**	-1.32**	-5.04**	-0.65**	-1.08**	-2.63**	-43.54**	-317.20**	-202.18**
15	ICSB 687	-1.61**	-4.42**	-5.13**	-16.67**	-27.37**	-3.39**	1.48**	1.63**	1.51**	4.15**	0.54**	3.05**	-18.62	132.80**	90.32**
16	ICSB 77	0.73**	1.50**	-2.13**	-20.50**	-20.62**	-23.78**	-0.64**	0.03	-1.52**	0.38**	-0.33**	0.52**	-32.51**	-100.54**	-60.51**
17	ICSB 88001	-0.51*	1.23**	-0.93*	14.25**	15.64**	15.68**	1.85**	2.89**	2.39**	2.47**	0.22*	2.10**	126.06**	-207.20**	99.82**
18	ICSB 88006	0.23	1.50**	6.37**	3.07*	10.47**	9.89**	-0.71**	1.43**	0.88**	-1.85**	0.28**	-1.04**	-77.81	-317.20**	-68.84**
19	ICSB 89003	0.89**	2.33**	1.21**	11.87**	-10.25**	6.82**	2.29**	-0.13	2.31**	0.65**	-0.88**	0.14	19.46	-50.54**	39.49*
20	ICSB 89004	-0.11	1.33**	8.87**	-53.17**	-54.52**	-19.81**	-0.17	6.03**	3.81**	2.25**	1.02**	0.12	51.86	72.80**	67.82**
21	ICSB 9	-1.61**	-0.17	3.12**	-8.72**	-24.17**	6.89**	2.88**	0.51	1.94**	-1.50**	-1.21**	-1.40**	-69.47**	-92.20**	-44.68
22	ICSB 90001	4.18**	2.83**	3.30**	-33.54**	-42.43**	-12.87**	3.23**	2.90**	3.84**	1.53**	0.90**	1.05**	-65.74	-131.49**	-50.75**
23	ICSB 91002	-1.61**	-0.67**	-4.13**	-41.77**	-28.92**	-59.06**	1.93**	1.83**	-4.94**	1.25**	0.02	-1.53**	14.21	32.8	-102.18**
24	IESB 2	-1.41**	-0.67**	1.07**	-27.91**	-21.02**	-17.74**	-1.79**	-1.93**	-2.31**	1.37**	0.09	0.45**	-48.89**	-207.20*	-152.18**
25	MB 6	-4.94**	-5.50**	-7.79**	25.40**	33.82**	13.12**	-3.51**	-4.40**	-3.51**	-2.02**	0.12	-0.06	-146.1**	216.13**	109.49**

Appendix XV continues

		Days to 50% flowering			Plant height (cm)			Panicle length (cm)			Panicle width (cm)			Yield (t/ha)		
No	Parent	KBK	MIW	UKR	KBK	MIW	UKR	KBK	MIW	UKR	KBK	MIW	UKR	KBK	MIW	UKR
26	SDSB 1	1.61**	2.12**	5.45**	11.82**	25.53**	25.25**	-1.57**	-0.11	0.89**	-1.67**	-0.41**	-1.32**	-39.51**	-38.63	18.54
27	SDSB 4	4.39**	4.17**	7.21**	-8.07**	-13.62**	10.06**	5.53**	4.67**	4.61**	-1.15**	-0.80**	-0.89**	-22.98*	-217.20**	66.16
28	ICSB 73	1.2**	-0.25	1.11	3.70**	1.8	10.44**	-5.91**	-8.03**	-1.51**	-1.66	1.65	0.39**	-20.82	-47.1	-99.22**
	Male parents															
1	AIHR91075	-1.61**	-3.17**	-5.13**	-24.97**	-18.62**	-28.01**	-0.97**	-3.77**	-5.84**	-0.45**	-0.63**	-2.08**	65.31**	-167.20*	-102.18**
2	GADAM	-5.11**	-4.67**	-3.13**	8.03**	4.38	7.29**	-0.87**	-2.57**	-4.04**	-0.65**	0.47**	-0.58**	51.26**	132.80**	157.82**
3	ICSR 108	0.39	1.08**	-0.13	-12.47**	-14.97**	-25.96**	1.08**	0.18	-0.11	1.40**	-0.21	0.90**	-16.47	-142.20*	-89.68**
4	ICSR 153	-2.61**	-0.17	-6.13**	-20.27**	3.18	-27.61**	1.43**	-1.32**	-5.04**	-0.65**	-1.08**	-2.63**	-143.5**	-317.20**	-202.18**
5	ICSR 160	0.06	2.33**	0.54	-14.20**	-13.15**	0.69	2.16**	5.38**	0.28	1.45**	0.13	-0.11	30.37*	-83.87**	22.82
6	ICSR 162	1.04**	0.83**	-0.13	24.18**	14.24**	14.35**	0.94**	1.10**	1.60**	-0.01	0.18	0.75**	-7.98	-38.63	34.97
7	ICSR 172	0.49	-0.87**	0.17	-41.97**	-36.78**	-23.59**	-1.45**	-1.38**	-1.30**	-1.75**	-0.49**	-1.33**	-18.72	-7.2	-12.18
8	ICSR 196	0.39	3.33**	0.37	-27.27**	-18.82**	-8.91**	-0.57**	1.13**	-1.54**	-0.25	0.42**	-0.88**	-14.49	-217.20*	-127.18**
9	ICSR 23019	0.89**	1.33**	-2.63**	46.33**	28.43**	22.04**	1.83**	2.03**	-1.09**	0.55**	-0.63**	1.37**	38.61**	-167.20**	247.82**
10	ICSR 24007	-4.11**	-0.67**	-1.13*	-58.27**	-60.92**	-46.91**	-3.07**	-0.57	-6.29**	-0.05	-0.08	-1.48**	-156.7**	-667.20**	-202.18**
11	ICSR 24008	3.73**	1.50**	0.87	-26.53**	2.95	-21.06**	3.26**	1.30**	2.73**	3.55**	-0.67**	2.46**	66.96**	-350.54**	-165.51**
12	ICSR 24009	3.14**	3.71**	3.12**	-13.84**	-37.69**	-4.49**	3.43**	0.27	2.01**	1.17**	-1.22**	-1.60**	-5.6	-742.20**	-27.18
13	ICSR 24010	-1.86**	2.08**	3.37**	49.43**	37.48**	32.04**	-4.22**	-0.99**	-1.29**	0.40*	0.12	2.37**	-32.29*	-42.20**	21.82**
14	ICSR 38	-1.61**	-0.67**	-4.13**	-41.77**	-28.92**	-59.06**	1.93**	1.83**	-4.94**	1.25**	0.02	-1.53**	4.21	32.8	-102.18**
15	ICSR 43	4.23**	2.33**	7.54**	-30.50**	-21.15**	5.02**	3.89**	6.92**	4.51**	-0.12	0.95**	-0.29	-92.76**	82.8	14.49
16	ICSR 56	-0.61*	-0.17	0.87	1.23	-17.42**	7.39**	0.73**	-1.72**	1.41**	-2.25**	-1.28**	-0.93**	-57.54**	-367.20**	97.82**
17	ICSR 89001	0.89**	4.83**	4.37**	-48.67**	-61.62**	-40.21**	5.03**	5.03**	2.51**	1.25**	2.67**	-0.78**	73.66**	-917.20**	-152.18**
18	ICSR 89028	-0.11	1.33**	8.87**	-53.17**	-54.52**	-19.81**	-0.17	6.03**	3.81**	2.25**	1.02**	0.12	11.86	132.80**	47.82*
19	ICSR 89058	0.56*	2.00**	3.04**	-25.00**	-47.05**	-6.34**	4.36**	3.87**	3.58**	0.31*	-0.32*	-0.43**	-40.96**	-50.54**	-35.51
20	ICSR 89059	2.39**	4.33**	6.87**	-14.47**	-16.72**	7.49**	6.23**	4.43**	5.66**	-1.25**	-1.13**	-0.13	14.56	-167.2	-27.18
21	ICSR 92003	2.89**	2.33**	3.12**	-22.62**	-24.87**	6.49**	1.28**	0.88*	4.16**	0.60**	0.69**	0.47**	-19.84	-167.20*	-89.68**
22	ICSR 93001	1.39**	2.08**	1.62**	7.13**	9.73**	10.29**	0.68**	3.78**	0.91**	-0.95**	1.24**	-0.15	40.88**	107.8	-14.68

Appendix XV continues

		Days to 50% flowering			Plant height (cm)			Panicle length (cm)			Panicle width (cm)			Yield (t/ha)		
No	**Parent**	**KBK**	**MIW**	**UKR**	**KBK**	**MIW**	**UKR**	**KBK**	**MIW**	**UKR**	**KBK**	**MIW**	**UKR**	**KBK**	**MIW**	**UKR**
23	ICSR 93034	2.64**	-2.67**	-1.13*	46.53**	22.78**	15.31**	1.58**	0.23*	4.71**	2.60**	-0.18	2.37**	241.61**	57.3	-77.18**
24	ICSV 95022	1.39**	-0.17	-7.6**	-34.17**	-42.22**	-18.91**	4.13**	1.58**	2.56**	0.25	-0.28*	1.82**	-23.89	-367.20**	222.82**
25	IESV 23010 DL	-4.11**	-5.17**	-10.1**	10.33**	11.73**	1.59	-3.62**	-2.19**	-3.41**	-1.15**	-0.21	-0.38*	-71.47**	357.80**	82.82**
26	IESV 23011DL	-0.44	-0.67**	-0.13	23.47**	21.32**	9.67**	1.69**	-0.02	0.14	3.45**	0.48**	1.66**	79.57**	99.46**	42.82
27	IESV 23013 DL	-2.11**	-1.67**	-3.13**	51.83**	56.98**	22.89**	0.23	-3.07**	-2.24**	1.15**	-1.28**	1.72**	7.56	-317.20**	97.82**
28	IESV 23019 DL	2.89**	-1.17**	4.87**	61.23**	39.78**	51.99**	1.63**	-1.27**	3.76**	0.65**	-0.98**	2.12**	78.36**	-167.2	347.82**
29	IESV 91104 DL	0.56*	-0.17	3.04**	37.23**	51.48**	25.61**	-2.82**	-3.75**	-1.41**	0.62**	0.85**	0.23*	100.32**	166.13**	126.99
30	IESV 91131 DL	-0.44	0.17	6.21**	-32.10**	-31.25**	-12.58**	-0.24	0.18	-0.37	-2.39**	-0.70**	-2.31**	-56.41**	149.46	-43.84
31	IESV91136DL	-1.11**	-0.17	-1.13*	-27.97**	-13.12**	-21.41**	1.23**	2.68**	0.76**	-0.35*	-0.53**	-1.58**	60.96**	232.80**	47.82*
32	IESV92156DL	-0.11	2.33**	-2.13**	-15.17**	-16.32**	-23.21**	1.43**	-0.07	2.76**	-1.55**	-0.03	0.17	-80.44**	382.80**	-152.18*
33	IESV92158DL	0.89**	0.33	0.87	-18.27**	-23.72**	-22.81**	0.23	-1.57**	-0.09	-1.75**	-0.28*	-0.48**	-69.04**	282.80**	97.82**
34	IESV92172 DL	-0.11	-2.67**	-2.13**	-21.67**	-20.12**	-16.71**	3.73**	-1.27**	0.81**	-0.45**	-0.73**	-1.78**	131.61*	232.80*	272.82**
35	KARI MTAMA 1	-0.27	-1.75**	0.04	30.28**	26.23**	11.14**	-2.97**	-0.66	-0.66*	-0.54**	1.06**	1.05**	53.83**	82.8	86.99**
36	*MACIA*	-2.86**	-1.42**	-5.19**	-23.27**	-10.14**	-18.75**	0.83**	-0.62	-0.54*	0.1	-0.70**	-0.38*	-18.38	-67.2	41.55*
37	MAKUENI LOCAL	-4.77**	-3.67**	-4.29**	46.23**	37.42**	34.42**	-2.61**	-1.72**	-0.32	-0.09	0.30*	1.84**	-104.5**	-433.87**	87.82**
38	S35	-4.61**	-5.42**	-9.38**	18.93**	42.03**	10.94**	-3.17**	-3.67**	-4.14**	-2.10**	0.27	-0.95**	-90.32**	307.80**	97.82**
39	SIAYA # 66 – 2	3.39**	4.83**	3.37**	-12.27**	21.38**	-10.96**	-9.42**	-10.8**	-6.69**	-2.20**	-0.53**	-0.93**	-87.24**	-217.20**	-152.18**
40	SIAYA #46-2	0.89**	1.83**	4.37**	57.53**	52.78**	16.19**	-1.97**	-1.47**	-2.59**	-0.85**	0.07	-0.88**	99.16**	-267.20*	-227.18**
41	SIAYA#42	-0.61*	-1.67**	5.37**	-19.47**	-29.52**	-3.71*	-5.17**	-4.72**	-2.34**	-2.05**	-0.18	-1.28**	-91.74**	32.8	-77.18**
42	SP 74278	-4.11**	-2.17**	-7.63**	-23.27**	-29.52**	-23.11**	-2.47**	-1.37**	-5.44**	-2.05**	-0.73**	-2.23**	-107.3**	332.80**	-252.18**
43	SP 74279	-3.11**	-3.17**	-12.1**	-37.27**	-48.52**	-25.61**	0.03	3.38**	-5.19**	-3.05**	-0.73**	-2.63**	-162.2**	-1017.20**	-252.18**
44	TEGEMEO	-2.61**	-0.17	-4.63**	40.23**	71.48**	17.89**	-1.82**	0.83*	-1.19**	-0.85**	1.27**	0.67**	-91.44	282.80**	147.82**
45	BUSIA #28-1	3.89**	1.83**	3.87**	31.73**	78.18**	32.69**	-7.77**	-10.0**	-0.34	-1.55**	-0.73**	-0.43**	25.61	82.80**	-77.18**
46	R8602	-3.11**	-3.67**	-7.63**	-34.47**	-51.92**	-29.81**	-1.87**	-0.67	-0.74**	-1.85**	-0.48**	-0.93**	-97.54**	-107.20**	-27.18

Note: *, ** significant at 5% and 1% level respectively; KBK = Kiboko site; MIW = Miwaleni site; UKR = Ukiriguru site

Appendix XVI. Specific combining ability (SCA) affects of sorghum hybrid parents across dry low land and sub-humid environments during 2011-2012 seasons

No	Cross	Days to 50% flowering	Productive tillers	Plant height (cm)	Panicle (cm)	Panicle length (cm)	Panicle width (cm)	Yield (t/ha)
1	ATX623×GADAM	1.63	0.01	-1.94	0.17	0.39	0.24	104.35
2	ATX623×ICSR23019	1.63	0.01	-1.94	0.17	0.39	0.24	104.35
3	ATX623×ICSV95022	1.63	0.01	-1.94	0.17	0.39	0.24	104.35
4	ATX623×IESV91104DL	-0.02*	-0.22	-11.08	-0.44	0.13	-0.05	276.99**
5	ATX623×IESV91131DL	0.36	-0.29	-3.26	0.05	0.36	0.67	242.71
6	ATX623×IESV91136DL	1.63	0.01	-1.94	0.17	0.39	0.24	-104.35
7	ATzX623×KARI-MTAMA1	0.33	-0.01	-6.29	0.07	-1.34	-0.88	-170.08
8	ATX623×*MACIA*	2.99*	1.15**	-8.08	0.82	1.71	0.3	198.6
9	ATX623×MAKUENI LOCAL	2.08*	0.28	-7.09	-2.5	0.7	-0.61	-173.07
10	CK60A×IESV23010DL	3.76*	-0.56	10.43	-6.96**	3.08**	0.48	237.7
11	CK60A×KARI-MTAMA1	-1.95*	0.69	-4.33	-0.42	0.65	1.15*	332.3**
12	CK60A×SP74278	5.43*	-0.56	15.42*	-3.72*	2.48**	0.59	-109.65
13	CK60A×R8602	5.43*	-0.56	15.42*	-3.72*	2.48**	0.59	-109.65
14	ICSA11×ICSR172	2.96*	-0.46	13.60*	-1.99	0.42	1.04*	136.06
15	ICSA11×S35	5.19*	-0.04	18.95**	-5.66**	3.45**	1.81**	-192.46
16	ICSA11×SP74279	4.52*	-0.25	14.72*	-1.43	1.75*	1.40**	-182.1
17	ICSA12×ICSR162	-0.75	-0.48	3.37	1.28	-0.5	-0.4	-113.89
18	ICSA12×ICSR172	-2.27*	-0.55	-7.81	0.73	1.47	0.41	435.19*
19	ICSA12×ICSR93001	-1.87	0.16	-21.24**	-0.82	0.39	0.28	-162.14
20	ICSA12×IESV23019DL	-0.7	-0.04	-11.06	0.21	0.06	0.23	-179.4
21	ICSA12×IESV91104DL	0.69	0.24	-4.07	0.38	0.17	0.64	212.52
22	ICSA12×IESV92156	-0.7	-0.04	-11.06	0.21	0.06	0.23	-179.4
23	ICSA12×IESV92158DL	-0.7	-0.04	-11.06	0.21	0.06	0.23	-179.4
24	ICSA12×IESV92172DL	-0.7	-0.04	-11.06	0.21	0.06	0.23	-179.4
25	ICSA12×KARI-MTAMA1	1.33	-0.26	-1.97	-0.84	-0.71	-0.05	249.4**
26	ICSA12×SIAYA46-2	-0.7	-0.04	-11.06	0.21	0.06	0.23	-179.4
27	ICSA15×ICSR160	-0.91	0.16	-16.26*	0.94	1.68	-0.27	-130.05
28	ICSA15×ICSR162	0.65	-0.58	-15.51*	-2.01	1.62	0.17	-451.76*
29	ICSA15×ICSR172	-0.37	0.76	4.47	0.65	0	-0.12	-287.29
30	ICSA15×IESV91104DL	0.42	0.07	-14.62*	0.66	-1.1	-0.66	267.83**
31	ICSA15×TEGEMEO	0.03	-0.1	-13.98*	0.16	-1.27	0.34	-379.47*
32	ICSA276×ICSR162	-0.19	0.21	8.89	1.62	-1.81*	-0.76	293.94
33	ICSA276×ICSR24008	-1.81	-0.1	-18.44**	2.62	-1.47	-2.45**	187.94
34	ICSA276×IESV91104DL	-1.76	0.3	-31.26**	-1.37	2.30**	0.56	-559.44**

Appendix XVI continues

No	Cross	Days to 50% flowering	Productive tillers	Plant height (cm)	Panicle (cm)	Panicle length (cm)	Panicle width (cm)	Yield (t/ha)
35	ICSA293×ICSR24009	-3.32**	0.34	18.67**	1.26	-1.90*	0.55	258.33
36	ICSA366×KARI-MTAMA1	1.58	0.03	-3.06	0.88	0.66	-0.52	-211.51
37	ICSA366×*MACIA*	2.24*	0.07	-2.11	0.77	0.88	0.33	-130.65
38	ICSA371×*MACIA*	3.15**	-0.01	17.39**	0.53	0.11	0.33	165.71
39	ICSA376×IESV23013DL	2.30*	-0.11	-43.90**	-9.62**	1.69	-0.53	170.61
40	ICSA44×ICSR172	1.9	0.35	-18.79**	2.83	-0.3	-1.69**	-177.43
41	ICSA44×IESV91104DL	-0.48	-0.18	-17.27**	-2.87	1.65	0.55	191.9
42	ICSA44×MAKUENI LOCAL	1.74	-0.04	-7.29	-2.93*	4.24**	1.08*	-216.06
43	ICSA479×SIAYA66-2	-3.87**	-1.83**	0.62	7.08**	8.99**	1.22**	485.54*
44	ICSA6×ICSR162	-0.47	-0.78	-17.81**	-3.75*	-0.35	-0.17	314.71
45	ICSA6×ICSR93034	0.99	-1.35**	-43.25**	1.54	-1.77*	-2.34**	-140.22
46	ICSA6×IESV23011DL	-0.31	-0.04	-2.89	2.95*	-1.87*	-1.26**	144.12
47	ICSA654×ICSR153	2.97**	-2.44**	14.90*	-3.37*	1.64	1.45**	187.64
48	ICS687×ICSR162	-2.16*	-1.36**	-15.58*	1	-2.13*	-1.02*	168.71
49	ICS687×IESV23011DL	1.99	-0.12	-20.16**	-3.41*	0.31	-1.15*	-272.11
50	ICSA77×ICSR108	-0.95	0.45	14.97*	-1.29	0.1	-0.54	151.61
51	ICSA77×ICSR160	-1.81	-0.14	8.42	2.65	-3.47**	-0.22	-170.16
52	ICSA77×ICSR196	-0.03	0.04	21.63**	-0.92	0.71	-0.19	231.19
53	ICSA88001×ICSR108	0.98	-0.32	-8.52	2.75	-1.77*	-1.25**	106.68
54	ICSA88001×ICSR160	2.79**	0.02	0.3	-1.97	-1.14	-0.96*	179.04
55	ICSA88001×ICSR93034	-1.35	1.10*	12.52*	1.49	-1.53	-0.3	130.39
56	ICSA88001×KARI-MTAMA1	0.59	-0.73	-0.91	1.63	1.26	0.61	-178.79
57	ICSA88001×*MACIA*	-0.25	-0.04	-10.07	1.77	-0.44	-1.09*	96.11
58	ICSA88006×ICSR162	-0.91	-0.28	1.54	1.4	-0.46	-0.07	165.43
59	ICSA88006×IESV91131DL	-1.48	0.2	-17.00**	0.14	-0.9	0.68	119.84
60	ICSA88006×KARI-MTAMA1	0.49	0.42	0.63	-1.33	1.72	0.36	-272.33
61	ICSA89003×ICSR89058	-1.14	0.19	0.25	-0.85	-1.64	0.12	188.62
62	ICSA89003×ICSR92003	-3.23**	0.81	0.89	0.52	-2.62**	-1.24**	-48.09
63	ICSA89003×IESV23011DL	0.13	-1.85**	20.50**	1.8	-2.39**	-1.18*	-46.58
64	ICSA 89004×ICSR89028	-3.37**	0.49	42.50**	3.17*	-3.22**	-1.13*	-264.16
65	ICSA9×ICSR56	-0.45	0.56	8.67	-3.16*	-1.77*	1.37**	152.12
66	ICSA9×ICSR89058	-1.45	0.57	20.40**	-0.85	-2.30**	0.26	165.86
67	ICSA90001×ICSR162	-1.82	0.89*	10.76	3.08*	-4.51**	-2.17**	53.02
68	ICSA90001×ICSR172	-1.67	0.11	15.76*	0.25	-0.66	0.56	187.22
69	ICSA90001×ICSR24008	-0.77	0.41	26.06**	2.71	-1.41	0.04	-77.28
70	ICSA90001×ICSR43	-3.10**	0.49	13.99*	-1.6	-2.87**	0.2	34.01
71	ICSA90001×ICSR89001	-3.44**	0.25	29.61**	3.70*	-3.32**	-1.16*	129.33

Appendix XVI continues

No	Cross	Days to 50% flowering	Productive tillers	Plant height (cm)	Panicle (cm)	Panicle length (cm)	Panicle width (cm)	Yield (t/ha)
72	ICSA90001×ICSR89058	-2.77**	0.26	14.81*	0.41	-2.65**	-0.14	-99.18
73	ICSA90001×ICSR92003	-1.69	-0.35	25.91**	1.35	-2.19*	0.11	241.28
74	ICSA91002×ICSR38	2.13*	0.51	43.25**	-1.77	0.39	0.09	121.72
75	IESA2×ICSR24007	0.33	0.16	22.22**	5.18**	2.01*	-0.64	136.09
76	IESA2×ICSR24008	-2.67*	-0.13	22.82**	-0.37	0.97	-0.47	392.20*
77	IESA2×ICSR24009	-2.46*	0.08	-5.27	-0.88	-0.37	0.23	229.93
78	IESA2×ICSR24010	-1.17	0.36	4.84	5.88**	0.6	1.03*	218.34
79	IESA2×SIAYA42	0.33	0.16	22.22**	5.18**	2.01*	-0.64	136.09
80	MA6×IESV23010DL	7.74**	-0.24	-19.13**	-6.43**	3.20**	0.76	-165.12
81	MA6×MAKUENI LOCAL	4.02**	-0.11	-23.73**	-4.23**	2.98**	-0.18	-173.37
82	MA6×S35	5.41**	-0.46	-28.35**	-5.44**	2.10*	0.25	-272.81
83	SDSA1×ICSR24009	-0.68	0.43	-14.49*	0.59	1.32	-0.27	94.64
84	SDSA1×ICSR24010	-1.56	0.18	-3.48	0.02	1.67	-0.54	-159.05
85	SDSA1×ICSR43	-4.06**	0.23	-11.95	6.00**	-1.05	0	172.67
86	SDSA1×ICSR93001	-1.89	0.18	-10.68	1.75	-0.07	1.08*	85.94
87	SDSA1×IESV91104DL	-3.00**	0.18	-3	0.79	-0.59	-0.79	332.34
88	SDSA1×IESV91131DL	-3.00**	0.46	-10.35	0.01	0.66	0.89	173.01
89	SDSA1×BUSIA28-1	-3.06**	0.38	-20.86**	0.72	0.26	1.13*	123.2
90	SDSA4×ICSR24009	-2.71**	0.33	27.65**	1.68	-3.45**	-0.46	154.43
91	SDSA4×ICSR43	-4.59**	0.72	10.59	2.94*	-4.07**	0.72	-149.01
92	SDSA4×ICSR89059	-5.26**	0.81	3.88	2.92*	-4.94**	0.95*	211.34
93	SDSA4×SIAYA46-1	-1.44*	-1.24**	0.99	0.08**	-1.94**	1.26*	-89.71

*, ** significant at 5% level