ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Genetic Diversity study in Sorghum (*Sorghum bicolor (*L.*)* Monench) Germplasm Accessions Collected from the Major Drought-prone areas of Ethiopia Based on Quantitative and Qualitative Traits

By

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July, 2008

Acknowledgement

I express my sincere gratitude and indebtedness to my advisors Dr. Kifle Dagne and Prof. Masresha Fetene for their strong advice and unreserved technical support and follow up in the whole part of my thesis research, starting from proposal development to the end of the work. Their ability to facilitate each and every working conditions and sense of understanding during the whole part of my work is highly appreciated.

This work was fully sponsored by the Bio-EARN Project on Sorghum. I am highly indebted and appreciate all the team members of this project. The School of Graduate Studies and the Department of Biology of AAU are highly acknowledged for accepting me as MSc student and for administering the finance of this study.

I deeply acknowledge and appreciate Ethiopian Agricultural Research Institute for providing me study leave with payment as part of its staff development program. My special thanks go to Ato Gemechu Keneni for his valuable support in many part of my work and for sharing me his rich experience in the area of plant breeding. I do have also a special thank to my colleague Ato Zelalem Mengiste for his fertile ideas and encouragement during the whole part of my work. I also extend my special thank to Ato Solomon Tadesse for his kind support and encouragement during field data collection.

The Institute of Biodiversity Conservation (IBC),is also highly appreciated for providing me sorghum germplasm accessions used in this study. I am highly indebted to Ethiopian Agricultural Institute in general, Melkasa Agricultural Research Center and Dera Sub center in particular, for providing facilities and support during my field work. I am highly grateful to Melkasa Agricultural Research Center, National Sorghum Improvement Program staff members for their help in various aspects to successfully complete the field research work. Here, it is extremely special to thank Dr.Tesfeye Tefera for his valuable advice and comments starting from the proposal writing to end of my work. I do have also special thank for Ato Tilahun for his special support during field work. I extend my thanks to Ato Geremew and Ato Teferi from Dera sub center for their genuine support during the whole part of the field work at Dera.

My special thanks go to the staff member and the management unit of Holetta Agricultural Research Center Particularly Horticulture Research Division and Plant Biotechnology Research project for their valuable support in my work. I sincerely acknowledge Ato Gemechu Keneni, Ato Musa Jarso, Dr.Girma Taye, Ato Adugna Abdi, Ato Menilik and Dr. Amsalu Ayana for their support in statistical data analysis. The encouragement of my parents W/o Beletu Tegegn and Ato Bekele Beshah and my sister Belaynesh Bekele also highly appreciated.

Finally I would like to thank my wife Sr. Almaz Getu for her endless patience and full care for our son, Eyuael Dagnachew. Certainly, I could not have reached this stage with out her support.

Finally, I would like to give all glory and honor to my Lord and Savior, Jesus Christ, who have made it all possible.

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Abstract

In Ethiopia, the extent of genetic diversity among sorghum germplasm collections from drought prone areas has not been well studied. To determine the extent of genetic diversity among different sorghum genotypes grown in major moisture stressed areas of Ethiopia, a total of 495 sorghum accessions were evaluated at two representative moisture stress areas. Thirteen quantitative and six qualitative traits were used in this study. For the quantitative traits, univariate, bivariate and multivariate statistical methods were applied to analyse the genetic diversity. Moreover, the phenotypic diversity between the accessions and regions of origin were estimated based on the qualitative traits using Shannon-Weaver diversity index (H′). Analysis of variance revealed significant difference among the accessions for all quantitative traits. Based on their field performance in moisture stress areas, 95 potential drought tolerant sorghum accessions were identified for further evaluation. Moreover, cluster analysis grouped the test accessions into eight clusters with different genetic distance between each cluster. Maximum genetic distances were obtained between clusters C_7 & C_8, C_4 & C_8, and C_6 & C_7 with D^2 190.78, 160.95 and 147.98, respectively. In principal component analysis, the first four principal components explained 62.09% of the total variation, indicating existence of high genetic diversity among the accessions. Furthermore, all the qualitative characters showed high diversity in their distribution as well as in the amount of variation. The overall average phenotypic diversity (H′) among accessions was 0.82, varying from 0.66 for inflorescence exertion to 0.93 for grain color. The partitioning of the phenotypic diversity into within and between regions of origins indicated that 87 % of the total variation was within regions of origin, while only 13% was found between regions of origin. Therefore, this study confirms the existence of very high genetic diversity in sorghum germplasm accessions grown in the drought prone areas of Ethiopia, providing a great opportunity to isolate a number of promising parents with good traits related to drought tolerance, for crossing to develop drought tolerant/resistant sorghum varieties.

Key words: Sorghum, Genetic diversity, Drought, Ethiopia, Quantitative traits, Qualitative traits

1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench 2n = 20) is the fifth most important cereal in the world after wheat, rice, maize and barley (FAO, 2003). Grain sorghum serves as one of the most important staple cereals for millions of poor in semi-arid tropics of Africa and Asia, where annual rainfall is minimum and recurrent drought is common (Grenier *et al.*, 2001). It is used to make syrup, ethanol, silage and brooms in different part of the world. Moreover, the stalk and leaves are used as feed for livestock, for construction and for fuel (Rooney and Miller, 1982).

As reported by Rooney (2000), the cultivated races of sorghum were domesticated in northeastern Africa, where the greatest variability of this species is still found. Cultivated sorghum is classified into 15 races primarily based on their panicles and spikelets morphology (Harlan and de Wet, 1972). These include 5 basic races which include bicolor, caudatum, durra, guinea and kafir. The remaining 10 are intermediate races originated from all possible combinations of the basic races. Ethiopia is a major center of diversity for the intermediate race, durra-bicolor, and one of the centers of diversity for race durra (Doggett, 1988). All the races, except Kafir, and the corresponding intermediate races are naturally found in Ethiopia (Dahlberg, 2000).

The adaptation of sorghum to the range of environmental conditions in semi-arid Africa has resulted in the evolution of extensive genetic variation for drought tolerance (Doggett 1988). In major sorghum growing regions of Ethiopia, rainfall is inadequate and its distribution is erratic (Reddy and Kidane, 1993). In these areas, there is always risk of crop failure due to drought stress. Thus, the development of drought tolerant sorghum varieties is an important objective of the sorghum breeding programs in Ethiopia. To develop drought tolerant sorghum varieties, the first step is to characterize and estimate the extent of the genetic diversity of sorghum germplasm accessions associated to drought.

According to Gebrekidan (1981) in Ethiopia, sorghum exists in tremendous diversity throughout the growing areas with an extremely broad and valuable genetic base for potential breeding and improvement program in the country and in the world. Moreover, both in the national and international sorghum improvement programs, the importance of Ethiopian sorghum germplasm is well recognized (Kebede, 1991).

Success in plant breeding is enhanced through a more complete knowledge of germplasm contribution and a careful understanding of the genetic relationships between genotypes in a given gene pool (Gill, 1989). In any crop, progress from selection depends on the magnitude of genetic diversity between parents, because crosses among parents with maximum genetic diversity are more responsive to improvement for a given trait and allow a larger segregation and recombination of different favorable alleles (Negassa, 1986).

Information on the genetic diversity within and between populations is particularly useful in detecting genetic materials with novel genes. In Ethiopia a number of sorghum germplasm collections have been characterized and the existence of considerable genetic diversity in both cultivated and wild sorghum has been reported (Teshome *et al.*, 1997; Geleta, 1997; Ayana and Bekele, 1998, 1999, 2000). However, many of these studies did not give much emphasis for drought and others were made in areas with relatively better rainfall. More over out of more than 8, 000 sorghum accessions collected in Ethiopia (Dahlberg, 2000), only a small number was characterized both at the morphological and molecular level.

Furthermore, the development of high yielding and stable varieties for the drought affected areas needs a continuous supply of new germplasm as a source of desirable genes. However, in Ethiopia, the extent of genetic diversity among sorghum germplasm collections from drought prone areas has not been well studied. This study was, therefore, designed to examine the magnitude of genetic diversity among sorghum germplasm accessions collected from the major drought-prone areas of Ethiopia based on the quantitative and qualitative morphological traits.

2. LITERATURE REVIEW

2.1. Origin and domestication

Sorghum [*Sorghum bicolor (*L.) Moench 2n = 20] is the fifth major cereal crop in the world (Smith, 2000).The cultivated sorghum is originated from the wild member of S. *bicolor subspecies verticiliflorum* (Sun *et al.,* 1994; Aldrich and Doebley, 1992; Doggett, 1988). As reported by Harlan and de Wet (1972) the race *verticiliflorum* first gave rise to the race bicolor type, which is the most primitive of all basic races of subspecies *bicolor*. As suggested by Mann *et al* (1983) with the possible exception of race *kafir,* the other races are thought to be modifications of the early bicolor type.

Harlan and de Wet (1972) classified traditional sorghum cultivars into five main races (bicolor, caudatum, durra, guinea, and kafir) and 10 intermediates races, mainly on the basis of the morphology of panicles and spikelets. Of the five basic races, four races (bicolor, caudatum, durra, and guinea) are reported to be found in Ethiopia (Stemler *et al*., 1977). According to Harlan (1992) the intermediate races involving these four basic races also widely occur in Ethiopia. Ethiopia is a major center of diversity for the intermediate race durra-bicolor, and one of the centers of diversity for race durra (Dahlberg, 2000).

The cultivated races of sorghum were domesticated in northeaster Africa, where the greatest variability of this species is still found (Rooney, 2000). According to Kimber (2000) sorghum domestication has been associated with human migrations, trade, and shipping routes through Africa, and through the Middle East to India. The same author reported that sorghum was first taken to the western hemisphere through the slave trade and nowadays, cultivated sorghum is found in a wide range of environments in Africa, Asia, Australia and North, South and Central America.

2.2. Sorghum Production and Breeding Efforts

Drought stress is the most important problem for sorghum production all over the world and most of the sorghum growing areas of Africa are drought prone (Rasew, 1987). According to House (1985), its adaptation to stress environments makes sorghum an important major cereal in the semi-arid regions where drought and poor soil conditions make the production of other cereals difficult. Sorghum has a number of morphological and physiological characteristics that contribute to its adaptation to dry conditions including dense and extensive root system, waxy bloom on the leaves that reduces water loss and the ability to stop growth in periods of drought and to start growth again when conditions become favorable (Younis et.al, 2000).

More than 78% of the world area under sorghum lies within Africa and Asia (FAO, 2003). In Africa, over 24 million hectares of land is allotted for sorghum production (Dingkuhn *et al.,* 2005). Nigeria is the largest producer of grain sorghum in Africa where, annually 7 million metric tons are produced on 6.6 million hectares of land and Sudan is the second largest African producer of grain sorghum, followed by Burkina Faso and Ethiopia (Smith, 2000).

In Ethiopia the importance of sorghum is well recognized, particularly in the lowland areas where rainfall is unreliable and crop failures due to recurrent drought are common (Kebede and Menkir, 1987). It is the best crop in the drought stressed lowland areas that cover 66% of the total arable land in the country (Gebeyehu *et al., 2004*). In the country, every year, sorghum is cultivated on about 1.3 million hectares of land contributing about 1.7 million metric tons of annual grain production (CSA, 2005). However, the productivity of the crop is very low, only about 1.4 ton/ha, but experimental results indicate that yield of up to 3.5 ton/ha is possible on farmers field in major sorghum growing regions of Ethiopia (Geremew *et al.,* 2004).

Although several factors such as low soil fertility, poor pest and disease control and low yield potential of local cultivars contribute to low yield in sorghum, much of the reduction in yield is due to severe drought stresses (Boyer, 1982). In major sorghum growing regions of Ethiopia, rainfall is inadequate and its distribution is erratic (Reddy and Kidane, 1993). As a result the crop suffers from water deficits at least for certain period during the growth season. In most areas where crop production is dependent of rainfall, there is always risk of crop failure or yield loss due to drought stress.

The development of drought tolerant crops is an important objective in many plant breeding programs. The drastic effect of drought in sorghum can be overcome by growing varieties that have the desired traits for drought along with reliable soil and water conservation practice. Growing sorghum varieties that withstand moisture stress has been particularly considered as the most effective methods to enhance the crop production in moisture stress condition (Tunistra *et al.,* 1996).

Breeding for drought tolerance while maintaining maximum productivity under optimal conditions has been difficult (Rosenow *et al.,* 1983, 1997). However, many improvements in yield performance of sorghum in stressful environments have been addressed through traditional plant breeding method by selecting suitable genotypes with the ability to withstand the effect of moisture stress and produce high and stable yield across locations and years (Ejeta *et al*., 1999).

In Ethiopia, many efforts have been made to address the drought problem in sorghum. The Sorghum Breeding Program in Ethiopia has released a number of varieties for lowland areas which give reasonable yield in drought prone areas (Adugna, 2007). Currently, sorghum breeding in Ethiopia is fully engaged in different research activities in sorghum drought tolerance.

So far, two sources of stay green, B-35 and E-36-1 were identified by ICRISAT and in use in different part of the world to generate drought tolerance/resistance sorghum varieties (Borrell *et al.,* 2001). The same author reported that, most of such studies have dependent upon the donor line B-35, but introgression of stay green trait into farmers preferred sorghum cultivars using B-35 as a donor parent has been limited by extensive linkage-drag associated with this line. Moreover, the E 36-1 derived sorghum drought resistance needs further characterization (Borrell *et al.,* 2000). Therefore, there is a big interest to isolate other best sorghum genotypes with good stay green properties from Ethiopian sorghum gene pool through proper screening of germplasm accessions.

2.3. The Significance of Genetic Diversity

Genetic diversity within and between a given plant populations is the product of an interaction of biotic and abiotic factors, artificial selection and plant characteristics such as size, mating system, mutation, migration and dispersal (Frankel *et al.,*1995). Effective crop improvement programs mainly depend on the availability of crop genetic diversity. In domesticated crops, genetic diversity provides a source of variation for plant breeding program and is essential to decrease crop vulnerability to abiotic and biotic stresses (Bartett and Kidwell, 1998; Messmer *et al.,* 1992).

As reported by Franco *et al.* (2001), genetic diversity in cultivated crops is essential for successful breeding and creation of new cultivars for specific objective. It is a raw material for developing high yielding varieties and for maintaining the productivity of such varieties by incorporating the genes for abiotic stress tolerance such as drought as well as genes for disease and insect resistance. Hence, information about genetic diversity in the available germplasm is very important to develop the appropriate variety for specific purpose.

The importance of germplasm in the improvement of cultivated crops has been well recognized (Harlan, 1992; Frankel and Brown, 1984). Progress in any crop improvement program could be enhanced through a more complete knowledge of germplasm contribution and a thorough understanding of genetic relationships between genotypes in a given gene pool. Furthermore, knowing the genetic diversity of the available germplasm is necessary for identifying diverse parental combinations and creating segregating progeny with high genetic variability for selection.

Moreover, a wider genetic base of germplasm is a prerequisite for the success of a plant breeding program to cope up with several breeding challenges in a changing environment (Bechere *et al.,* 1996). According to Altieri (1987), in crop plants, the highest potential for genetic diversity are represented primarily by landraces, wild relatives of cultivated species and weedy species that contain genes for characters of adaptation to changing environment such as drought, disease and pest resistance. A landrace is a plant population which is adapted to local agro climatic conditions and which has been generated, selected, named and maintained by traditional farmers. Landraces being genetically heterogeneous have been used by plant breeders as the source of specific traits in the development of the improved varieties. The most important traits which are believed to be found in germplasm accessions includes earliness, resistance to drought and other stress conditions, disease and pest resistance and nutritional quality (Bechere *et al.,* 1996).

According to Rush (1991), genetic diversity is particularly of no value unless it encompasses genes that are useful, either in them, or in combination with other previously evaluated germplasm in order to meet the product required by farmers, processors and consumers. Plant breeders are primarily interested in utilizing the available germplasm for achieving specific breeding objectives. Hence, the required germplasm should consist of different types of genetic variability for yield; yield components, plant height, maturity and resistance to various stress conditions such as drought, heat etc. Plant breeders would thus like to diversify the source of useful variability for specific traits in germplasm collection to meet the future requirements (Wei *et al.,* 1997).

Plant breeding is essentially a selection of plants among the variables (Allard, 1988, 1996). Hence, progresses from selection depend on the magnitude of genetic diversity between parents, because crosses among parents with maximum genetic diversity are more responsive to improvement and allow a larger segregation and the combination of different favorable alleles (Negassa, 1986). Therefore, detecting the extent of genetic diversity present in crop species is extremely important as it allows effective selection. As a result, the concept of genetic relationship among individual germplasm accessions and populations has become an important tool for the effective utilization of genetic diversity in a given gene pool (Gill, 1989).

2.4. Genetic Diversity in Sorghum

Sorghum is a crop with extremely high genetic diversity in different part of the world (Subudhi *et al*., 2000). Genetic improvement in sorghum is very essential for farmers in semi-arid areas where it is the most important food crop. Information on the genetic diversity of sorghum germplasm accessions is particularly useful in characterizing individual accessions and detecting genetic materials with novel genes (Pecetti and Damania, 1996). Moreover, knowing the genetic diversity of sorghum germplasm is essential for identifying diverse parents that when combined would create segregating progeny with high genetic variability for selection.

Despite the importance of the sorghum crop all over the world, comprehensive genetic characterization has been limited (Subudhi and Nguyen, 2000). Similarly, as reported by Gill (1989) germplasm utilization of several crops including sorghum is limited in many developing countries like Ethiopia mainly due to lack of proper evaluation and characterization because of shortage of facilities, funds, trained man power and availability of limited variants of useful traits. Furthermore, proper evaluation of the germplasm for stress condition such as drought is limited because of inadequate facilities for simulation of drought, heat, frost and other stress conditions.

Categorizing germplasm accessions into morphologically and genetically similar groups is very useful for crop improvement programs (Subudhi and Nguyen, 2000). Many efforts have been made to identify the different accessions of Ethiopian sorghum germplasm based on morphological characters and molecular markers (Abdi *et al.,* 2002; Ayana and Bekele, 2000; 1999; 1998, Teshome *et al.*, 1997; Geleta, 1997; Gebrekidan and Menkir, 1979).

However, the extent of genetic diversity among sorghum germplasm collections from drought prone areas associated with drought has not been systematically quantified, while the development of high yielding and stable varieties for the drought prone area requires a continuous supply of new germplasm as a source of desirable genes. Therefore, there will be a continuous demand for broad genetic base sorghum cultivars that are high yielding and stable under abiotic and biotic stresses.

The primary sources of such genes are landraces, weedy, and wild relatives of crop plants (Prasada Rao *et al.,* 1995; Harlan, 1992).The availability of these germplasm requires the identification of areas of diversity of various characters of agronomic importance, especially within the centers of diversity (Bekele, 1984). For effective use, the existing genetic resources needed to be characterized into appropriate groups for various purposes for the current and the future plant breeding programs.

2.5. Estimation of Genetic Diversity

Estimation of genetic diversity in crop plants can assist in the evaluation of different germplasm accessions as possible sources of genes which can improve the performance of farmers preferred cultivars (Subudhi *et al*., 2000). Knowledge about genetic relationships among cultivars is usually obtained directly from plant characteristic data such as morphological traits, biochemical data and, more recently, on DNA based marker data (Schut *et al.,* 1997).Traditionally, genetic diversity estimates in crop plants were based on differences in quantitative and qualitative morphological traits (Schut *et al.,* 1997).

As reported by van Beuningen and Bush (1997) quantitative and qualitative morphological traits continue to be the first useful step in the study of genetic relationships in most breeding programs because statistical procedures for morphological trait analysis are readily available and the existing data bases on the germplasm collection can be used for genetic analysis. Moreover, morphological information is essential in understanding the idotype performance relationships of the genotypes.

Genetic diversity of morphological characters and multivariate analysis of quantitative characters has been used previously to measure genetic diversity within cereal crops in Ethiopia. Some of these are; Ethiopian wheats (Negassa, 1986), barley (Demissie and Bjornstad, 1996; Bekele, 1984; Tolbert *et al*., 1979), tetraploid wheat (Tesfaye *et al*., 1991; Bechere *et al*., 1996) and tef (Assefa *et al*., 1999).

On the other hand, genetic relationship evaluation among germplasm using morphological characters are lengthy and costly process (Cooke, 1984).The genetic control of many morphological characters is assumed to be complex often involving epistatic interaction (Schut *et al.,* 1997). Many morphological markers are recessive and therefore only expressed in homozygous condition. Further more, most morphological attributes are subjected to large genotypic environment interaction effect (Yee *et al.,* 1999*)*. Hence morphological appearance can not adequately describe accessions with out extensive replicated trials (Smith, 2000).

2.5.1. Quantitative traits

Estimation of genetic diversity among genotypes can be based on quantitative traits (Van Beuningen and Busch, 1997). Variation in most economically important quantitative traits of crop plants follows a continuous distribution caused by the action and interaction of many genes and various environmental factors. Statistical analysis of these quantitative traits, along with eco-geographic information is used for estimating genetic diversity in sorghum (de Wet *et al.*, 1976).

It is still widely used to quantify the amount and distribution of variation in large samples of sorghum germplasm collections (Ayana and Bekele, 1999; Teshome *et al.*, 1997).Using multivariate analysis procedures, Ayana and Bekele (1999) have revealed that the genetic variation in sorghum germplasm from Ethiopia and Eritrea was structured by environmental factors.

2.5.2. Qualitative traits

In sorghum, the earliest methods for estimating genetic diversity include Mendelian analysis of discrete morphological traits (Doggett, 1988). According to Teshome *et al.*, (1997) morphological traits, for which the variant allelic phenotypes are sufficiently discrete to allow their segregation to be followed, are the easiest and generally most economical of all markers to assay. Discrete morphological traits, though they have high heritability, are limited in number, each being conditioned by a few genes (Karp *et al.*, 1996, 1997). Thus, only a small portion of the genome could be covered. They are usually characterized by epistasis, pleiotropy and dominant-recessive relationships, further limiting their values as an ideal genetic marker. Besides, morphological characterization requires mature plants and the method involves a lengthy survey of plant growth that is labor intensive and time consuming (CIAT, 1993).

2.6. Genetic distance

According to Ejeta *et al*., (1999), analyses of the extent and distribution of genetic variation in a crop are essential for breeding programs to develop suitable variety for specific purpose. The pattern and the level of genetic diversity in a given crop gene pool can be measured in terms of genetic distance (van Beunign and Bush, 1997).

Genetic distance is a measure of the average genetic divergence between cultivars. Genetic distance estimates have been shown to be useful in many crops including sorghum to examine the level of genetic diversity of a given germplasm pool (Van Beunign and Bush, 1997) and to select parents to establish new base population and also to identify major groupings of related cultivars, breeding materials and genetic resources (Messemer *et al.,* 1993).

Several genetic distance measures have been used to quantify genetic relationships among cultivars or germplasm accessions. The first widely used approach involves the cluster analysis of pair wise genetic distances for the construction of dendrograms. One of the most commonly used genetic distance formula is the Euclidean distance, which is the square root of the sum of squares of the distances between the multidimensional space values of the distances for any two cultivars (Kaufman and Rouseeuw, 1998).

Genetic relationships among a large number of accessions can be summarized using different techniques to place similar accessions into groups. The pattern of genetic relationships or proximity among cultivars can be conveniently shown by multivariate techniques such as cluster analysis. Clustering techniques can present complex, multidimensional patterns of diversity (Sneller, 1994). Clustering is a useful tool for studying the relationships among closely related cultivars or accessions. In clustering analysis, cultivars are arranged in hierarchy by agglomerative algorithms according to the structure of complex pair wise genetic proximity measures. The hierarchies emerging from the cluster analysis are highly dependent on the proximity measures and clustering algorithm used (Kaufman and Rousseeuw, 1998).

Ordination is best suited to reveal interactions and associations among cultivars or accessions, which are described by continuous quantitative data (Bretting and Widrlechner, 1995). Principal component, principal coordinate and linear discriminate analyses are the ordination techniques most commonly used in genetic relationships and cultivar classification studies (Schut *et al.,* 1997). Generally, statistical methods such as univariate, bivariate and multivariate analysis can be applied to analyze the data generated from germplasm accessions.

3. Objectives

3.1. General Objective

To study the magnitude of genetic diversity among sorghum germplasm accessions from the major drought-prone areas of Ethiopia and to identify best drought resistant/tolerant sorghum genotypes.

3.2. Specific Objectives

To determine the degree of genetic diversity among different sorghum genotypes grown in major moisture stressed areas of Ethiopia based on quantitative and qualitative morphological traits.

To characterize and identify potential drought resistant/tolerant sorghum germplasm accessions from Ethiopian gene pool.

4. Materials and methods

4.1. Plant Materials

A total of 495 sorghum germplasm accessions and four checks, two standard varieties released for moisture stressed areas of Ethiopia (Meko and Seredo) and two varieties with stay green property (B-35-1 and E-36-1) were used in this study (Appendix.1). Among these, there were two hundred thirty sorghum germplasm accessions collected from different low land drought-prone areas of Ethiopia mainly from Central and South Tigray, North and South Wello, Kemise and North Shewa. During collection to avoid double collection of the same germplasm accession as that of Institute of Biodiversity Conservation (IBC), the pass port data was used. All the check varieties were received from the National Sorghum Improvement Program of Ethiopia

The other two hundred sixty three accessions were received from the Institute of Biodiversity Conservation (IBC) with their passport data. These accessions were collected from different parts of the country where recurrent drought is common, mainly from Tigray, Wello, Gamo Gofa, Hararghe; Shewa and Gondar (Fig 1). More over, from Bako research center two released varities Dano (BRC-378) and Lalo (BRC-24) which have stay green property were included in this experiment.

4.2. Geographic Locations of the study Sites

These accessions were grown in two representative moisture stressed areas of Ethiopia, at Melkassa Agricultural Research Center and Dera Sub-center. These areas are among the recommended testing sites for the dry lowland sorghum germplasm characterization in Ethiopia. Melkassa Agricultural Research Center is located in the Rift Valley at 39º21´E longitude, 8 º24´N latitude and with an altitude of 1550 meter above sea level. The soil type is silty loam with a pH of 7.2 and the area receives an average annual rainfall of 600mm.

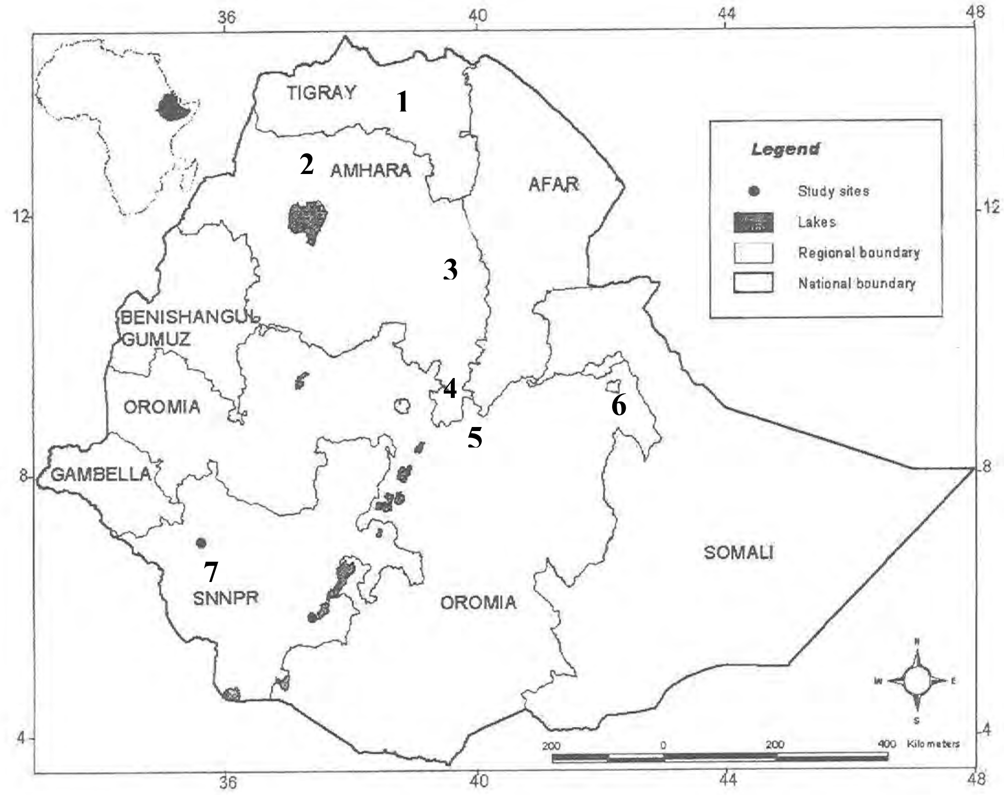
Dera Agricultural Research Sub-center is also located in Rift Valley at 39"0' N latitude and 08"04 E longitudes with an altitude 1600 meter above sea level. The sub-center is characterized with sandy loam soil type with a pH of 7.8 and the area receives average annual rainfall of less than 550 mm every year. For both locations the weather data during the growing seasons is presented in (Table 1)

At Melkassa the accessions were planted in the last week of April, while at Dera planting was done after the onset of the summer rain in the second week of June 2007. The experiment was laid down in an augmented design with 15 blocks. The four checks were replicated in every block. The spacing between plants and between rows was 0.15m and 0.75m, respectively. Each accession was planted in single raw of 4.5m and every plot contains 30 individual plants. At planting 100kg/ha DAP and the same rate of urea was applied. All the recommended agronomic practices such as weeding, cultivation, thinning etc were applied as required regularly.

Table1. Melkasa Agricultural Research Center and Dera Sub-center temperature and mean monthly rain fall data during the crop growing season in 2007

Melkassa Research Center				Dera Sub-center			
Month	Temperature (°C)		Rain Fall (mm)	Month	Temperature (°C)		Rain Fall (mm)
	Min.	Max.			Min.	Max.	
April	23	28	3.27	May	8.6	31.5	1.6
May	25	31	3.58	June	8.28	28.6	2.57
June	17.2	29.4	32.6	July	6.46	26.24	3.1
July	21.61	27.25	104.5	August	6.5	25.3	87.8
August	15.65	25.88	104.9	September	6.13	26.1	76.4
September	15.7	27.16	12	October	3.76	26.87	7.5
Mean	***19.69***	***28.12***	***43.48***	***Mean***	***6.29***	***27.44***	***29.83***

(Source: Melkassa Research Center and Dera Sub-center Agrometeorology)



Key

Regions of Collections

1. Tigray
2. Gonder
3. Wello
4. Kemise
5. North Shewa
6. Harerge
7. Gamo Gofa

Fig.1. Geographic locations from where the sorghum accessions have been collected.

4.3. Parameters measured

4.3.1. Quantitative Characters

Sorghum Descriptors (IBPGR/ICRISAT, 1993) was used for characterization and data collection (Table 2). In both locations, data were recorded from the middle row on five randomly selected individual plants, except for emergency percentage, percent stand establishment, days to 50% flowering, days to maturity and thousand seed weight which were recorded on plot basis. For leaf area, a procedure developed by Stickler *et al.* (1961) was used. Percent bird attack was also recorded for those accessions which were affected by birds to estimate the grain yield per panicle. Before measuring thousand seed weight and grain yield per panicle, the grain moisture content was recorded for individual plants and the moisture content of the grain was adjusted to 12.5%.

4.3.2. Qualitative Characters

To characterize each accession based on qualitative morphological trait, Sorghum Descriptors (IBPGR/ICRISAT, 1993) was used as in quantitative trait. For each trait five randomly selected individual plants were used for characterization. Below are lists of the qualitative traits, their descriptors and the codes used in data collection and analyses (Table 3).

4.3.3. Leaf senescence

Special focus was given during selection on specific traits that are expected to enhance drought tolerance. These include targeted selection of accessions for post flowering drought resistance that are characterized with retention of green leaves until grain filling period (stay green behavior). leaf senescence were also recorded using a 1-5 scale (1 being non-senescent and 5 full senescent) three weeks after the complete termination of rainfall to evaluate the genetic variation of each accessions for post flowering drought tolerance.

Table 2. Description of quantitative traits studied and the Code used for Characterization

Character	Code	Description
1. Emergency %	EM%	Percentage of total plant emerged
2. Stand establishment	SE %	Percentage of plant established from the total
3. Days to 50% flowering	DF	From emergence to when 50% of plants have started flowering
4. Leaf number (count)	LN	Count of total number of leaves per plant (main stalk).
5. Leaf length (cm)	LL	Length of the third or fourth leaf from the flag leaf.
6. Leaf width (cm)	LW	Width of the third or fourth leaf from the flag leaf.
7. Leaf area (cm^2)	LA	Area of the third or fourth leaf from the flag leaf, computed as (LL x LW x 0.747) suggested by Stickler et al. (1961).
8.Internode length (cm)	IL	Length of the third internode counted from the ground surface.
9. Plant height (cm)	PH	Height of the main stalk from the ground to the tip of the panicle.
10. Panicle length (cm)	PL	Length of panicle from its base to tip.
11. Panicle width (cm)	PW	Width of panicle in natural position at the widest part.
12. Days to maturity	DM	Number of days required for full maturity
13. Number of primary branches per panicle	NPB P	Number of branches arising directly from the rachis of the panicle.
14. 1000 seed weight (g)	TSWt	Weight of 1000 random seed counts
15.Grain yield per panicle(g)	GYPP	Weight of grain per panicle only from the main panicle

Table 3. Description of qualitative traits and their codes used in data collection and analysis

Character	Number of Phenotypic classes(n)	Phenotypic classes and their codes
1. Awns (at maturity)	2	Absent (0) and Present (1)
2. Leaf midrib color	3	White (1), dull green (2) and yellow (3)
3. Waxy bloom	4	Slightly present(3),Medium present (5), Mostly present(7) Completely present (9)
4. Inflorescence Exertion	4	Slightly exerted (1), Exerted (2), Well-exerted (3), and Peduncle re-curved/ goose (4)
5. Panicle compactness & shape	11	Very lax panicle (1), Very loose erect primary branches (2), very loose dropping primary branches (3), Loose erect primary branches (4), Loose drooping primary branches (5), Semi-loose erect primary branches (6), Semi-loose drooping primary branches (7), Semi-compact elliptic (8), Compact elliptic (9), and Compact oval (10), broom corn (11)
6. Grain color	9	White (1), Yellow (2), Red (3), Light brown (4), Brown (5), Red brown (6), Dark brown (7), Grey (8), and Straw (9)

5. Statistical analysis

5.1. Quantitative traits

5.1.1. Univariate and Bivariate Analysis

Raw data were recorded for grain yield per panicle and thousand seed weight was adjusted to 12.5% moisture content. For some accessions which were attacked by bird in the field, the grain yield per panicle was adjusted using the percentage of bird damage recorded during data collection. Using the check which occurs in every block, the raw data of all quantitative traits were adjusted for the block difference by

$$r_j = \frac{(\sum B_j - M)}{C}$$

Where, r_j is the adjustment factor for each blocks, B_j is checks in the jth blocks, M is sum of the check means and C is number of check varieties per block.

The analysis of variance for the standard checks was computed with SAS computer soft ware. Using LSD of the checks, the adjusted mean of all quantitative traits were compared for the existence of significance difference among each accessions. Moreover, the combined over location mean of all quantitative traits were used to assess the correlations of each traits using JMP computer software.

5.1.2. Multivariate Analysis

For multivariate analysis, the combined over location mean of each quantitative character was standardized to avoid differences in scales used in recording data on the different quantitative characteristics. Principal was component analysis (PCA) computed on the standardized data using the correlation matrix. Using average linkage method of SAS software all sorghum accessions were clustered based on their differences and similarities on the quantitative traits. The numbers of clusters were determined based on the pseudo F and the pseudo t^2 statistics.

The relationships among the clusters were assessed by measuring the genetic distances between clusters as D^2 (Mahalanobis's distance).

$$D^2_{ij} = (x_i - x_j)' \, cov^{-1}(x_i - x_j)$$

Where, D^2_{ij} is the distance between cases i and j; x_i and x_j are vectors of the values of the variables for cases i and j; and cov^{-1} is the pooled within groups variance-covariance matrix. The D^2 values obtained for pairs of clusters was considered as the calculated values of Chi-square (x^2) and tested for significance both at 1% and 5% probability levels against the tabulated value of (x^2) for 'N' degree of freedom, where N, is the number of characters considered (Singh and Chaudhary, 1985).

5.2. Qualitative characteristics

Phenotypic frequency distributions of the qualitative characters were calculated for all accessions and regions of origin. Using the SPSS computer software, the chi-square analysis was computed to detect the existing proportion of each phenotypic class for all qualitative traits within and between regions of origins. The Shannon-Weaver diversity index (H′) was computed using the phenotypic frequencies to assess the phenotypic diversity for each character for all accessions. The Shannon-Weaver diversity index as described by Hutcheson (1970) is given as:

$$H' = -\sum_{i=1}^{n} p_i \log_e p_i$$

Where, p_i is the proportion of the total number of accessions in the i^{th} class of an n-class character and n is the number of phenotypic classes of traits. H′ was estimated for all characters and each H′ value was divided by its maximum value ($log_e n$) in order to keep the value between 0–1.

6. Results

6.1. Variation in Phenotypic Performance

From the total of 495 sorghum accessions used in this study, due to their difference to withstand various degrees of moisture stress, 464 and 291 accessions at Melkassa and Dera, respectively gave a full record for all quantitative traits. In both locations, full records for all quantitative traits were obtained only for 277 accessions (Appendix.2). Among these, based on the combined over location mean, 100 accessions gave better grain yield per panicle than the best performed standard check Meko, which gave 54.5 gram(Appendix.3).

The rests of the accessions failed even to flower and mature particularly at Dera where there was severe post flowering moisture stress. Fifteen accessions (*Sorcoll-200/07, Sorcoll-201/07, Sorcoll-259/07, Sorcoll-275/07, Acc. No 239173, Acc. No 239233, BRC-378(DANO), Acc. No 69191, Acc. No 239218, Acc. No 204612, Acc. No 241722, Acc. No 231193, Acc. No 239156, Acc. No 241199, Acc. No 241693*) were totally failed to perform at both locations.

From both locations, 95 potential sorghum accessions for drought tolerance were considered for Single Plant Selection (SPS) based on their field performance for moisture stress. In the overall agronomic performances, these accessions were found to be good as compared to the rest of the accessions considered in this study and they gave better grain yield per panicle than the best performed check, Meko which gave 54.5 gram (Appendix.3, 4 and 5).

Table 4. Number of accessions considered for Single Plant Selection (SPS) based on their field performance at Melkassa and Dera

Origin	Acces. planted	No of Accessions selected for SPS*			Total No of Accessions selected
		Melkassa	Dera	Same accessions selected in both locations	
Tigray	167	15	15	2	28
Wello	132	22	13	1	34
Gamo Gofa	65	7	10	3	14
Hararghe	39	1	1	-	2
Kemise	45	3	3	-	6
Shewa	40	4	7	1	10
Gondar	7	-	1	-	1
Total	495	52	50	7	95

** SPS (Single Plant Selection)*

Low leaf senescence is the most apparent mechanism of drought tolerance in the accessions under consideration. About 6% of the total 277 original population had the lowest score of 1 for leaf senescence, while in the populations identified for single plant selection, this value was raised to 11.8% (Table 5). The best combination of traits for better relative agronomic performance and drought tolerance (the lowest leaf senescence score of 1) was observed in 11 accessions (*Sorcoll-099/07, Sorcoll-180/07, Sorcoll-231/07, Sorcoll-232/07, Sorcoll-246/07, Sorcoll-272/07, Sorcoll-273/07, Acc. No 237311, Acc. No 238439, Acc. No 235617 and Acc. No 202508*).

A number of others were also selected for better relative agronomic performance combined with better leaf senescence values of less than 2 where both standard checks (E 36-1 and B-35) had records of slightly more than 2. There are still other sets with leaf senescence scores of as high as 4 (*Sorcoll-096/07, Acc. No 239243, Acc. No 239238*) or with no records available (*Sorcoll-279/07, Acc. No 238440, Acc. No 235929 and Acc. No 213017*) but considered for selection (Table 5).

Table 5. Comparison between accessions identified for SPS and the original

population showing the relative improvement in leaf senescence through selection

Leaf senescence (1-5)	Percent of Population (%)		Names of selected accessions
	Original	Considered for SPS	
1.0	6	11.58	Sorcoll-099/07, Sorcoll-180/07, Sorcoll-231/07, Sorcoll-232/07, Sorcoll-246/07, Sorcoll-272/07, Sorcoll-273/07, Acc. No 237311, Acc. No 238439, Acc. No 235617 and Acc. No 202508
1.5	8.81	9.47	Sorcoll-045/07, Sorcoll-162/07, Sorcoll-239/07, Sorcoll-274/07, Acc. No 241720, Acc. No 235608, Acc. No 238401, Acc. No 241728, Acc. No 237285
2.0	17.19	16.84	Sorcoll-061/07, Sorcoll-087/07, Sorcoll-125/07, Sorcoll-137/07, Sorcoll-165/07, Sorcoll-178/07, Sorcoll-229/07, Sorcoll-244/07, Sorcoll-250/07, Sorcoll-258/07, Acc. No 239222, Acc. No 238447, Acc. No 241709, Acc. No 241705, Acc. No 242045, Acc. No 239239
2.5	23.90	27.38	Sorcoll-002/07, Sorcoll-044/07, Sorcoll-047/07, Sorcoll-055/07, Sorcoll-075/07, Sorcoll-107/07, Sorcoll-132/07, Sorcoll-140/07, Sorcoll-145/07,Sorcoll-147/07, Sorcoll-150/07, Sorcoll-160/07, Sorcoll-166/07, Sorcoll-169/07, Sorcoll-194/07, Sorcoll-235/07, Sorcoll-249/07, Sorcoll-277/07, Acc. No 235607, Acc. No 239240, Acc. No 239166, Acc. No 241725, Acc. No 69178, Acc. No 241715, Acc. No 239165, Acc. No 241184
3.0	26.42	17.9	Sorcoll-001/07, Sorcoll-008/07, Sorcoll-131/07, Sorcoll-134/07, Sorcoll-143/07, Sorcoll-148/07, Sorcoll-184/07, Sorcoll-203/07, Acc. No 241706, Acc. No 239162, Acc. No 238428, Acc. No 238441, Acc. No 239174, Acc. No 241185, Acc. No 242044, Acc. No 238449, Acc. No 235615
3.5	14.68	9.47	Sorcoll-116/07, Sorcoll-117/07, Sorcoll-135/07, Acc. No 239227, Acc. No 239223, Acc. No 238443, Acc. No 241710, Acc. No 239193, Acc. No 213008
4.0	2.52	3.16	Sorcoll-096/07, Acc. No 239243, Acc. No 239238
-	0.48	4.2	*Sorcoll-279/07, Acc. No 238440, Acc. No 235929 and Acc. No 213017*

Furthermore, comparison of the frequency distributions of leaf senescence for the original and the selected population clearly indicates the possibility of some level of improvement in the selected individuals, as selection for better genotypes tended to shift the mean for leaf senescence in the original population (3) down in the selected populations (2.5) just in one cycle of selection (Fig. 2).

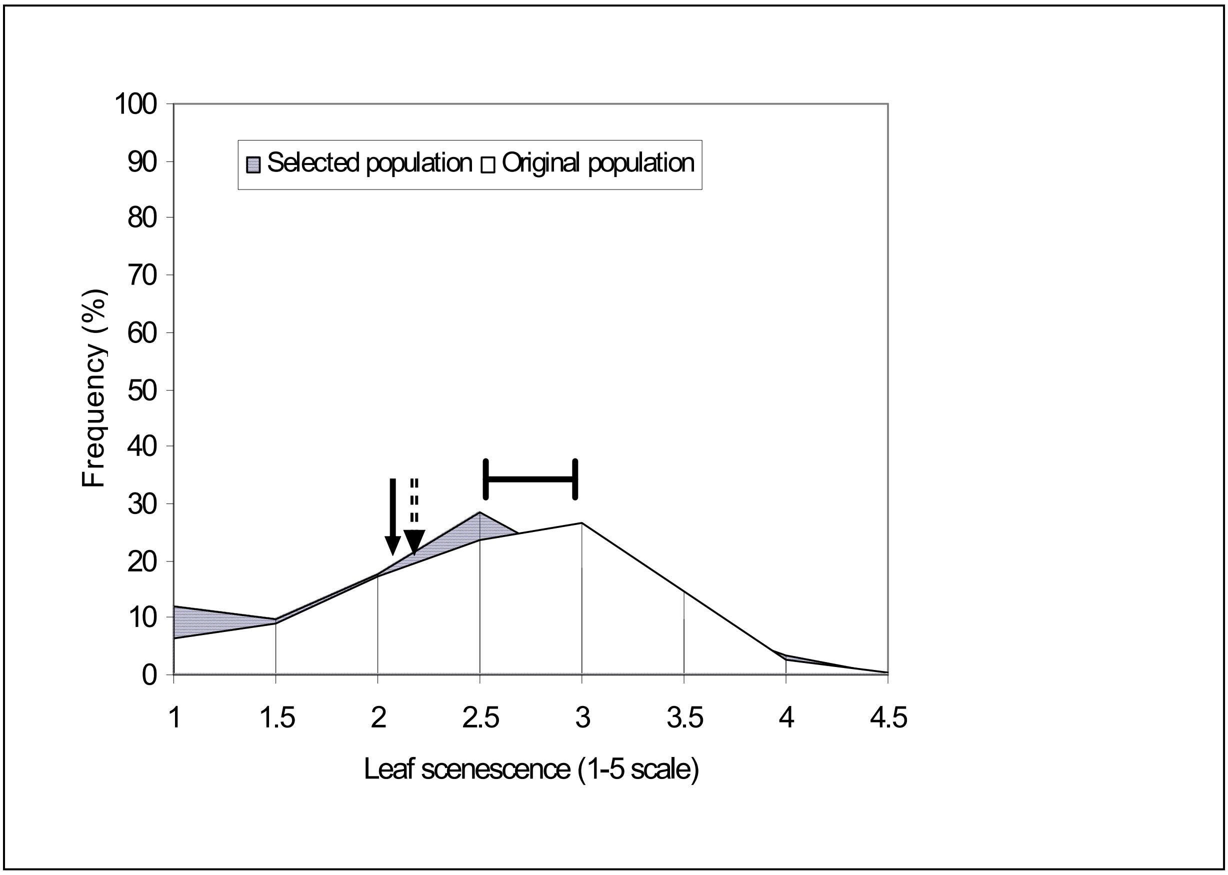


Fig 2. Comparison of frequency distributions for leaf senescence in 277 original and 95 selected populations of sorghum germplasm showing improvements for leaf senescence (the solid and broken arrows show positions of B-35 and E 36-1, respectively).

6.2. Quantitative traits

6.2.1. Univariate Analysis

For the quantitative characters, the mean comparison using the checks LSD revealed the existence of significant difference among accessions (Table 6).Based on the over location combined mean, the variation between the accessions was much greater for plant height, leaf area, grain yield per panicle, number of primary branches per panicle, number of days to maturity and number of days for 50% flowering (Appendix.2).

Accessions from Tigray showed the lower record for most of the traits, mainly for days to 50% flowering; number of days to maturity, plant height, leaf number, leaf length, leaf width and leaf area. On the other hand, the highest mean number of days to 50% flowering and numbers of days to maturity were observed for sorghum accessions collected from Kemise.

Accessions from Hararghe showed relatively the higher leaf number per plant, leaf area, and plant height and internodes length. Accessions from Gamo Gofa and Wello gave relatively the higher grain yield per panicle than the rest of the regions. Moreover, most accessions from Shewa showed an intermediate value for almost all the quantitative traits considered in this study (Table 7).

Table 6. LSD (0.05), CV% (Checks) and significant differences for 13 Quantitative traits among 277 sorghum accessions in two locations

Characters	Melkassa			Dera			Combined		
	LSD	Significance [@]	CV%	LSD	Significance [@]	CV%	LSD	Significance [@]	CV%
Leaf number	*0.75*	*	9.88	*0.97*	*	17.57	*0.58*	*	12.80
Leaf length	*3.22*	**	6.33	*4.49*	**	10.70	*2.70*	**	8.37
Leaf width	*0.48*	*	8.37	*1.03*	*	19.07	*0.51*	*	13.21
Leaf area	*37.04*	**	12.38	*49.03*	**	21.81	*29.52*	**	16.21
Plant height	*17.61*	**	16.71	*25.67*	**	21.51	*15.28*	**	19.56
Internodes length	*2.26*	**	22.21	*1.76*	**	19.58	*1.31*	**	19.73
Panicle length	*2.21*	**	16.80	*1.72*	**	15.22	*1.27*	**	14.99
Panicle width	*0.90*	*	20.42	*0.75*	*	17.01	*0.53*	*	17.45
Days to 50% flowering	*3.56*	**	6.03	*4.50*	**	7.51	*3.09*	**	7.48
Days to maturity	*5.54*	**	5.98	*3.68*	**	4.70	*3.37*	**	5.68
Number of primary branches per panicle	*6.79*	**	17.83	*7.85*	**	23.96	*4.76*	**	19.35
1000 seed weight	*2.55*	**	8.36	*4.17*	**	21.33	*2.34*	**	13.45
Grain yield per panicle	*18.79*	**	37.12	*10.58*	**	31.54	*10.40*	**	34.22

[@] *Refer to appendix. 2. for the combined mean significance difference for all quantitative characters between accessions.*

Table 7. Mean comparison for regions of origins of 277 sorghum accession based on 13 quantitative traits[@]

Origin	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
Tigray	11.12 c	69.69bc	7.06ab	384.73ab	221.53c	16.16b	17.70ab	6.33a	87.68e	129.65c	60.11b	31.37ab	49.51ab
Wello	11.77 bc	72.85b	7.79a	424.83a	240.68b	16.53ab	17.13ab	5.94c	96.05c	138.99a	57.81bc	30.20b	56.03a
Shewa	11.12c	69.97bc	6.78b	395.96ab	262.49a	15.09c	13.52	6.26b	93.40d	135.04bc	60.19b	30.02b	36.62c
Gamo Gofa	11.93b	74.30ab	7.38a	409.63a	249.09ab	16.61ab	18.65a	6.06b	99.97b	136.64bc	43.43d	28.40bc	58.20a
Kemise	12.10b	76.87a	7.07ab	412.20a	234.99bc	17.76a	17.59ab	6.81a	105.44a	141.29a	69.31a	27.61c	52.16a
Hararghe	13.30a	74.35ab	7.53a	423.12a	266.57a	18.93a	16.13b	6.44a	101.47b	131.79c	60.66b	32.14ab	54.92a
Gondar	10.36d	71.32b	7.13ab	384.86ab	230.92bc	16.50d	18.70a	6.51a	92.10d	133.82c	60.64b	33.59a	51.38a
LSD	*0.58*	*2.7033*	*0.5114*	*29..52*	*15. 29*	*1.31*	*1.27*	*0.53*	*3.10*	*3.371*	*4.76*	*2.34*	*10.4*

Notes: Levels not connected by same letter are significantly different

[@] *Quantitative traits abbreviations as indicated in Table 2.*

6.2.2. Bivariate Analysis

The correlation coefficient between most of the quantitative characters is highly significant ($P \leq 0.01$) and positive (Table 8).The highest significant positive correlation was obtained between leaf area and leaf width. Number of days to maturity is highly correlated with most of the characters including number of leaves per plant, leaf length, leaf width, leaf area, plant height and number of days to 50% flowering.

Grain yield per panicle is significantly correlated ($P \leq 0.01$) with all other characters except for number of days to maturity. However, thousand seed weight is negatively correlated with most of the quantitative traits considered in this study. Thousand seed weight is not significantly correlated with all quantitative traits considered in this study except with leaf number, leaf length, number of days for 50% flowering and number of days to maturity.

Table 8. Correlation coefficients between 13 quantitative traits in 277 sorghum Accessions.

	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt
LL	0.436 **											
LW	0.142 **	0.269 **										
LA	0.280 **	0.710 **	0.830 **									
PH	0.444 **	0.420 **	-0.022	0.207**								
IL	-0.098	0.032	-0.068	-0.001	0.368**							
PL	-0.090	0.070	0.127 *	.174**	0.272**	0.251**						
PW	0.190**	0.156**	0.117*	0.183**	0.143**	0.217**	0.223**					
DF	0.526**	0.526**	0.097	0.328**	0.493**	-0.060	0.009	0.046				
DM	0.475**	0.442**	0.156**	0.328**	0.383**	-0.077	-0.064	0.086	0.689**			
NPBP	0.244**	0.080	-0.021	0.039	-0.005	0.066	-0.104*	0.048	0.029	0.008		
TSWt	-0.124**	-0.204**	-0.045	-0.121*	-0.137*	0.071	0.052	-0.019	-0.327**	-0.284**	-.0068	
GYPP	0.166**	0.196**	0.166**	0.258**	0.287**	0.248**	0.250**	0.265**	0.166**	0.075	0.193 **	0.227**

Notes: @ *Quantitative traits abbreviations as indicated in Table 2.*
**, ** indicate correlation is significant at p = 0.05 and p = 0.01 probability level, respectively.*

6.2.3. Multivariate Analysis

6.2.3.1. Clustering of sorghum accessions

The multivariate analysis of thirteen quantitative traits grouped the test accessions in to eight different diversity classes (Table 9).In most cases, many accessions collected from the same region were clustered together. The number of accessions in each cluster varies from 1 to 119. Cluster one (C_1), is the largest cluster containing 119 accessions from the total of 277 sorghum accessions used in cluster analysis.The majority of the accessions in this cluster (62.2%) were collections from Tigray. The two stay green checks, B-35 and E-36 also fall in this cluster.

Moreover, cluster one (C_1) contains accessions with intermediate value almost for all quantitative characters except for number of primary branches per panicle, panicle length and panicle width (Table.10). Accessions in this cluster contain the highest mean value (61.69) numbers of primary branches per panicle and the lowest panicle length and panicle width, 16.08 and 5.88 respectively (Table.10). Many sorghum cultivars which are preferred by farmers for their reasonable yield in the drought affected areas were members of this cluster.

Cluster three (C_3) is the second largest cluster consisting of 51 accessions from the different regions. In this cluster accessions collected from Gamo Gofa were more abundant than those from the rest of the regions. Cluster six (C_6) contains 6 accessions all from Wello with the highest value for most of the characters including grain yield per panicle, plant height, days to 50% flowering and days to maturity.

Cluster seven (C_7), contains only one accession with the lowest value for most quantitative traits. Similarly cluster eight (C_8), contains one accession with the highest value of leaf length, leaf width and leaf area but with the lowest value of grain yield per panicle. The rest of the clusters contain different number of accessions from all regions.

The pair wise generalized square distance (D^2) between each cluster is shown in (Table.11).The genetic distance between most of the clusters was found highly significant ($P< 0.01$).The maximum genetic distance was obtained between clusters C_7 and C_8 with $D^2 = 190.78$. The second and the third most divergent clusters were C_4 and C_8 with $D^2 = 160.95$ and C_6 and C_7 with $D^2 = 147.98$, respectively. However C_1 didn't show significant difference with most of the clusters including C_2, C_3, C_4 and C_5.The lowest genetic distance between the cluster ($D^2 = 9.19$) was observed between C_1 and C_4.

The over location combined mean of the 13 quantitative traits was used to generate phenogram which clearly showed each distinct clusters (Fig 3). Moreover, based on the mean of 13 quantitative characters in each region, a dendrogram was obtained (Fig. 4.).In this dendrogram sorghum germplasm accessions collected from the drought prone areas of Tigray, Wello and Kemise showed close relationship. Accessions from Shewa & Hararghe and Gamo Gofa & Gondar also showed close relationship with each other.

Table 9. Distribution of 277 sorghum accessions into eight clusters by their origin using 13 quantitative characters

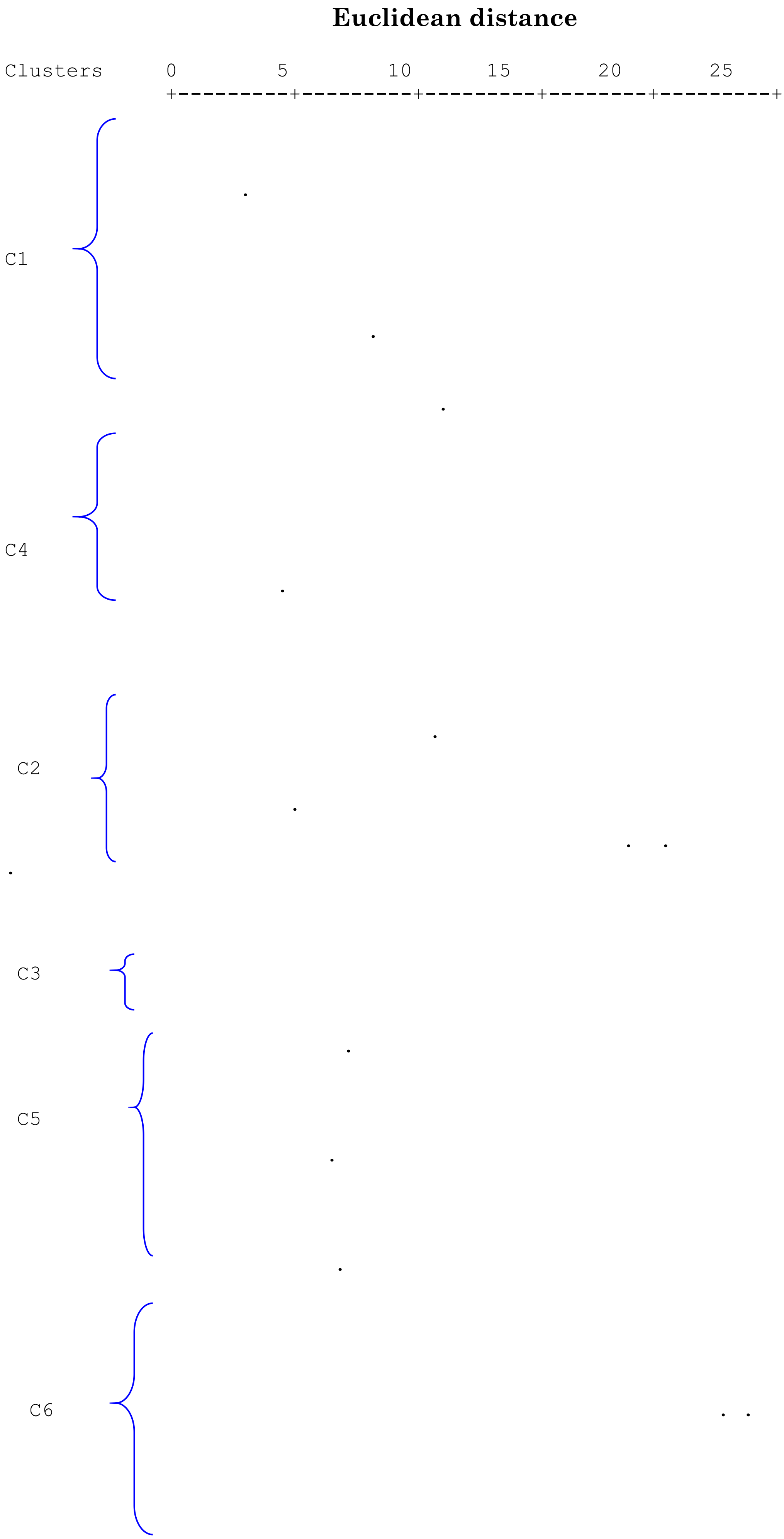
Cluster	Origin	No of Acces	* S.No of Accessions	Total No of Acces.
C1	Tigray	74	1,2,3,4,5,6,7,8,9,11,12,13,15,16,17,18,19,20,21,22,28,29,30,31,32,33,34,40,41,42,43,46,47,48, 49,50,51,52,53,55,56,57,58,59,60,61,65,66,69, 71,72,76,77,137, 150,152, 163, 169,171,173, 177,178, 192,193,197, 203,212,223,228,229, 236, 260,261,262	119
	Wello	23	80,83,84,85,86,87,88,92,94,95,96,98,99,101,106,108,109, 165, 172, 176, 182, 232, 238	
	Gamo Gofa	6	141,142,143,,217, 264,272	
	Kemisie	6	110,111,113,114,115,136	
	Shewa	5	121 ,123,125,126,127	
	Gondar	3	145, 160, 268	
	Hararghe	2	216, 277	
C2	Gamo Gofa	12	159, 175, 190, 215,218, 240,242, 250,251,252,259,266	33
	Wello	11	156, 183,184,188, 225,226, 234,235, 243, 253,, 274	
	Tigray	7	14, 158, 168, 207, 220, 273,167	
	Hararghe	3	195,196, 233	
C3	Gamo Gofa	16	149,153,154,157, 187, 202,204, 206, 213, 230,231, 239, 245, 254, 255,265	51
	Wello	14	81,91,100,103,104,105,107, 194, 201, 205, 224,263, 270,271	
	Tigray	11	24,39,63,64,73,74,75, 164, 189, 211, 222	
	Shewa	3	124,130,131	
	Hararghe	3	198,237,,258	
	Kemisie	3	133,134,135	
	Gondar	1	241	
C4	Tigray	19	23,25,26,37,38,44,45, 138,139, 144,146, 166, 179, 186, 191, 246,256,275,276	39
	Wello	3	79, 181, 199	
	Shewa	8	116,117,118,119,120,122,128,129	
	Gamo Gofa	7	140, 147,148,170, 180, 244, 247	
	Gondar	1	185	
	Kemisie	1	112	
C5	Tigray	14	10,27,35,36,54,62,67,68,70,78,174,210,214,227	27
	Wello	5	89,90,93,97,161	
	Gamo Gofa	7	151, 162, 248,249,257,267,269	
	Kemisie	1	132	
C6	Wello	6	155, 200, 208,209,219,221	6
C7	Wello	1	82	1
C8	Wello	1	102	1

* *Refer to appendix .2. for* S.No *(Serial Number) corresponding to the individual accessions and their performance for 13 quantitative characters*

Table 10. Cluster means for 13 quantitative characters in 277 sorghum accessions

Clusters	Quantitative characters												
	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
C1	11.74	70.29	7.25	380.53	217.46	15.95	16.08*	5.88*	90.16	131.62	61.69**	30.75	49.38
C2	12.59**	74.26	7.13	398.43	306.21	18.41	19.89	6.38	102.94	138.30	51.08	29.96	52.97
C3	12.33	76.10	7.97	454.49	247.69	16.81	18.02	6.69	98.88	141.19	52.57	30.17	62.54
C4	10.69	64.43	6.33	303.02	207.13	16.93	16.75	6.13	87.38	128.16	55.10	31.18	44.58
C5	11.31	75.35	8.59	480.33	185.75	13.85*	19.28	6.53	89.41	129.73	58.21	29.92	50.36
C6	12.53	78.78	8.99	537.55	306.76**	20.59**	22.53**	6.98	108.23**	150.53**	55.68	26.72	68.38*
C7	9.10*	49.63*	6.82*	255.82*	149.20*	11.67	18.09	7.32**	73.52*	111.88*	25.45*	33.25**	45.92
C8	11.00	83.02**	9.59**	613.75**	151.07	14.32	19.59	6.34	98.77	145.01	58.32	31.13	40.01*

*, ** *Lowest and highest mean values of the quantitative trait for all accessions in the cluster, respectively*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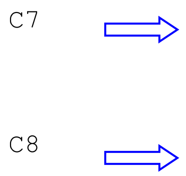

Figure 3. Phenogram showing cluster groups among the 277 sorghum accessions base on 13 quantitative traits data.

Table 11. Mahalanobis distance (D^2) of the eight clusters of 277 sorghum accessions based on 13 quantitative traits.

Cluster	C1	C2	C3	C4	C5	C6	C7
C1	0						
C2	11.99	0					
C3	9.92	12.43	0				
C4	9.19	22.14	34.48**	0			
C5	19.37	36.65**	9.15	51.56**	0		
C6	46.69**	32.57**	16.05	86.62**	27.86**	0	
C7	43.55**	79.26**	77.76**	26.58*	79.93**	147.98**	0
C8	101.55**	119.59**	62.50**	160.95**	38.92**	49.59**	190.78**

*Note: *, ** significant at p = 0.05 and p = 0.01 probability level, respectively*

Euclidean distance

```
                0         5        10        15        20        25
Origins         +---------+---------+---------+---------+---------+
 Shewa
 Harerge
 Wello
 Kemise
 Tigray
 GamoGofa
 Gonder
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Fig.4. Dendrogram showing the clustering pattern of the region of origins for sorghum accessions based on average linkage hierarchical cluster analysis.

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6.2.3.2. Principal component analysis

The first four principal components with eigenvalues greater than one accounted for a cumulative variation of 62.09%. Leaf length, days to 50% flowering, plant height, leaf area and days to maturity were the most important traits contributing to the first principal components. The contribution of internodes length, panicle length and grain yield per panicle in the second principal component analysis was also very high. Leaf width, number of primary branches per panicle and thousand seed weight were the most important traits in the third, fourth and fifth principal components, respectively.

Table 12. Principal Component analysis of 13 quantitative traits in 277 sorghum accessions.

Characters	PC1	PC2	PC3	PC4
Leaf number	0.34	-0.22	-0.12	0.24
Leaf length	0.41	-0.05	0.08	-0.05
Leaf width	0.23	0.05	0.62	-0.13
Leaf area	0.38	0.05	0.49	-0.12
Plant height	0.39	0.19	-0.37	0.05
Internodes length	0.06	0.48	-0.21	0.21
Panicle length	0.10	0.47	0.04	-0.01
Panicle width	0.15	0.27	0.07	0.30
Days to 50% flowering	0.40	-0.19	-0.26	-0.13
Days to maturity	0.36	-0.24	-0.18	-0.13
Number of primary branches per panicle	0.05	-0.17	0.05	0.65
1000 seed weight	-0.17	0.24	0.11	0.02
Grain yield per panicle	0.20	0.33	0.04	0.25
Eigenvalues	3.71	1.93	1.64	1.42
% Variance	26.49	13.75	11.69	10.16
% Cumulative	26.49	40. 24	51.93	62.09

Tigray and Wello Collections

Gamo Gofa Collections

Wello and Shewa Collection

Harerge Collections

Fig 5. Diversity in some sorghum accessions collected from different regions

6.3. Qualitative traits

6.3.1. Distribution of Qualitative Characters

The percentage frequency distributions of the phenotypic classes for each qualitative trait in all collection regions are given in Table 13.The chi-square analysis revealed the existence of highly significant difference for all qualitative characters considered in this study (Table 13 and 14).

All characters exhibited large diversity in their patterns of distribution and amount of variation. For all regions of origin, the most abundant phenotypic classes were the sorghum accessions with awn, white leaf midrib colour, compact & semi-compact elliptic panicles, exerted inflorescence, medium waxy bloom and white grain colour. The highest frequencies of awned sorghum accessions were recorded for collections from Wello, Harerge and Tigray with 75%, 75% and 69%, respectively.

The most abundant phenotypic class for panicle compactness and shape in most of the collection regions were compact and semi compact panicle. From the eleven phenotypic classes considered for panicle compactness and shape, the compact elliptic and the semi compact elliptic panicles were 26% and 47 % , respectively (Table 14).

For all regions of origin, the distribution of phenotypic classes for leaf mid-rib color showed that, maximum mean value (66 %) was white leaf midrib color and the lowest mean value was dull green leaf midrib color with 13 %. White grain color takes the leading proportion with 37 % followed by red, straw and brown with 19%, 13% and 9%, respectively in all regions of origin.

Table.13. Percentage of phenotypic classes for six qualitative traits and Chi-square (x^2) values for each collection areas

Regions of origin	Awns				Leaf midrib colour					Waxy bloom					Inflorescence Exertion					
	Phenotypic classes		*df*	x^2	Phenotypic classes			*df*	x^2	Phenotypic classes			*df*	x^2	Phenotypic classes				*df*	x^2
	0	1			1	2	3			3	5	7			1	2	3	4		
Tigray	31	69	*125*	*407.9****	50	13	36	*250*	*945****	34	55	10	*250*	*942.7****	30	63	5	3	*375*	*1523.8*
Wello	25	75	*63*	*271.3****	61	13	25	*126*	*473****	19	71	9	*120*	*503.6****	45	50	2	3	*189*	*841***
Gamo			*45*	*202.7****										*437****						
Gofa	33	67			83	7	10	*90*	*343.6****	26	68	6	*90*		43	54	2	0	*90*	*372.8**
Harerge	25	75	*7*	*27****	88	0	13	*7*	*40****	25	75	0	*7*	*40****	0	75	0	25	*7*	*40****
Shewa	34	66	*15*	*55****	61	14	25	*30*	*111.6****	26	49	25	*30*	*110.9****	51	48	1	0	*30*	*84****
Gonder	33	67	*5*	*22.8****	67	13	20	*10*	*34.4***	33	50	17	*10*	*60****	23	60	13	3	*15*	*52.9***
Kemise	40	60	*10*	*23.3****	55	27	18	*20*	*55.7***	38	60	2	*20*	*61.2****	18	64	9	9	*30*	*125.4**

Note: *For the codes used in each phenotypic class, refer Table 3 and df = degree of freedom.*
, **, and * are significant at p= 0.05, 0.01 and 0.001, respectively*

Table.13. *Continued...*

Regions of origin	Panicle compactness & shape													Grain colour										
	Phenotypic classes													Phenotypic classes										
	1	2	3	4	5	6	7	8	9	10	11	*df*	x^2	1	2	3	4	5	6	7	8	9	*df*	x^2
Tigray	0	0	1	0	0	5	5	57	24	7	1	*750*	*2725****	17	8	19	6	6	9	3	6	26	*1000*	*4171****
Wello	0	0	0	0	1	7	3	49	29	8	3	*378*	*1325****	26	5	18	8	9	6	6	5	17	*504*	*2221****
Gamo Gofa	0	0	2	0	0	15	10	48	4	2	19	*270*	*1031****	13	2	11	9	14	19	16	3	13	*360*	*1736****
Harerge	0	0	0	0	0	0	0	28	33	33	8	*21*	*91.25****	13	13	25	13	25	0	0	0	13	*10*	*25.8***
Shewa	0	0	0	0	0	5	10	41	25	19	0	*60*	*193****	43	5	8	13	8	6	0	6	13	*105*	*448.3****
Gonder	0	0	0	0	0	0	0	60	40	0	0	*5*	*16.67***	77	10	13	0	0	0	0	0	0	*10*	*25.8***
Kemise	0	0	0	0	0	0	0	47	25	18	9	*30*	*101.5****	73	0	9	0	0	0	9	0	9	*30*	*165****

Note: *For the codes used in each phenotypic class, refer Table 3 and df = degree of freedom.*
, **, and * are significant at p= 0.05, 0.01 and 0.001, respectively*

Table14. Percentage frequency distribution in different phenotypic classes for six qualitative traits and Chi-square (x^2) values for the six qualitative traits by region of origin

Regions of origin	Awns		Leaf midrib colour			Waxy bloom			Inflorescence Exertion			
	Phenotypic classes		Phenotypic classes			Phenotypic classes			Phenotypic classes			
	0	**1**	**1**	**2**	**3**	**3**	**5**	**7**	**1**	**2**	**3**	**4**
Tigray	31	69	50	13	36	34	55	10	30	63	5	3
Wello	25	75	61	13	25	19	71	9	45	50	2	3
Gamo Gofa	33	67	83	7	10	26	68	6	43	54	2	0
Harerge	25	75	88	0	13	25	75	0	0	75	0	25
Shewa	34	66	61	14	25	26	49	25	51	48	1	0
Gonder	33	67	67	13	20	33	50	17	23	60	13	3
Kemise	40	60	55	27	18	38	60	2	64	18	9	9
Mean	*32*	*68*	*66*	*13*	*21*	*29*	*61*	*10*	*37*	*52*	*5*	*6*
df	*6*		*12*			*12*			*18*			
Chi-squares	*8*		*107.4****			*66.6****			*174.99****			

*Note: *, **, and *** are significant at p= 0.05, 0.01 and 0.001, respectively and df = degree of freedom*
For the codes used in each phenotypic class, refer to Table 3

Table14. *Continued….*

Regions of origin	Panicle compactness & shape											Grain colour								
	Phenotypic classes											Phenotypic classes								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Tigray	0	0	1	0	0	5	5	57	24	7	1	17	8	19	6	6	9	3	6	26
Wello	0	0	0	0	1	7	3	49	29	8	3	26	5	18	8	9	6	6	5	17
Gamo Gofa	0	0	2	0	0	15	10	48	4	2	19	13	2	11	9	14	19	16	3	13
Harerge	0	0	0	0	0	0	0	28	33	33	8	13	13	25	13	25	0	0	0	13
Shewa	0	0	0	0	0	5	10	41	25	19	0	43	5	8	13	8	6	0	6	13
Gonder	0	0	0	0	0	0	0	60	40	0	0	77	10	13	0	0	0	0	0	0
Kemise	0	0	0	0	0	0	0	47	25	18	9	73	0	9	0	0	0	9	0	9
Mean	*0*	*0*	*1*	*0*	*0*	*4*	*4*	*47*	*26*	*12*	*6*	*37*	*6*	*15*	*7*	*9*	*6*	*5*	*3*	*13*
df	*42*											*48*								
Chi-squares	*320****											*351****								

*Note: *, **, and *** are significant at p= 0.05, 0.01 and 0.001, respectively and df = degree of freedom*
For the codes used in each phenotypic class, refer Table 3

6.3.2. Estimation of Genetic Diversity

The existing phenotypic diversity between the accessions and regions of origin was estimated based on Shannon-Weaver diversity index (H′). Individual traits differ in their distribution and patterns of variation. Each qualitative trait showed different levels of diversity index in different regions. The mean Shanon diversity index (H') pooled across characters within region of origin ranged from 0.58 for Harerge to 0.80 for Tigray, indicating the existing very high diversity for Tigray collection than the rest of the regions (Table 15).

The region that had the highest H' were Tigray, Wello and Shewa, whereas the lowest values of H' for regions of origin was obtained from Harerge and Gonder. Awn and leaf midrib color showed high diversity index in all regions (Table 15). Among the 6 qualitative traits measured in all sorghum accessions, the highest diversity index (H') was obtained for grain colour, awn, panicle compactness & shape and leaf midrib color. On the other hand, the trait that showed the lowest average diversity index in this study was inflorescence exertion.

In this study high phenotypic diversity was detected for all qualitative characters considered. Among the 6 qualitative traits measured in all sorghum accessions, highest diversity index (H') was obtained for grain colour, awn, panicle compactness & shape and leaf midrib colour. On the other hand, the traits that showed the lowest average diversity index in this study was inflorescence exertion. The overall average phenotypic diversity (H′) among accessions was 0.82, varying from 0.66 for inflorescence exertion to 0.93 for grain colour (Table 16).

Furthermore, estimation of phenotypic diversity based on Shannon-Weaver diversity index (H′) indicates 87% of the total variation was found within regions of origin, whereas only 13% phenotypic variation was obtained between regions of origin (Table 16).

Table 15. Estimates of H′ for six qualitative characters in 277 sorghum accessions by regions of origin

Origin	Awn	Leaf midrib color	Waxy bloom	Inflorescence exertion	Panicle Compactness	Grain Color	Mean	Std Err Mean
Tigray	0.89	0.89	0.84	0.64	0.60	0.91	0.80	0.056
Wello	0.82	0.84	0.71	0.64	0.65	0.92	0.76	0.046
Gamo Gofa	0.91	0.51	0.70	0.56	0.71	0.95	0.72	0.073
Harerge	0.81	0.50	0.51	0.41	0.62	0.79	0.58	0.079
Shewa	0.92	0.84	0.95	0.50	0.68	0.80	0.78	0.069
Gonder	0.92	0.54	0.92	0.66	0.62	0.21	0.75	0.121
Kemise	0.86	0.91	0.61	0.80	0.59	0.40	0.70	0.078
Mean	*0.87*	*0.69*	*0.75*	*0.60*	*0.64*	*0.71*	*0.70*	*0.056*

Table16. Estimates of H′, partitioning into within and between regions of origin for six qualitative characters in 277 sorghum accessions

Characters	H'	Hr	Hr/H'	(H' - Hr)/H'
Awn	0.88	0.87	0.99	0.01
Leaf midrib colour	0.83	0.69	0.83	0.17
Waxy bloom	0.80	0.75	0.93	0.06
Inflorescence Exertion	0.66	0.60	0.91	0.09
Panicle compactness & Shape	0.84	0.64	0.76	0.24
Grain colour	0.93	0.71	0.77	0.23
Mean	*0.82*	*0.70*	*0.87*	*0.13*

Notes: H′ = *Diversity index for each character calculated from entire data set;*
H_r = *Average diversity index of each character for the seven regions of origin;*
H_r/H' = *Proportion of diversity within regions of origin;*
$(H'-H_r)/H'$=*Proportion of diversity between regions of origin in relation to the total variation.*

Fig 6. Diversity in panicle compactness & shape and grain color between sorghum genotypes

Fig 7. Diversity in panicle compactness and shape within test accession

7. Discussion

7.1. Quantitative traits

7.1.1. Univariate Analysis

The extent of phenotypic diversity in 277 sorghum accessions from the drought prone areas was studied based on morphological quantitative traits under the existing moisture stressed conditions at Melkasa and Dera. The result showed the existence of high diversity among accessions. There was evidence that both natural selection for adaptation to a given environment and farmers selection for specific use accounted for most of the morphological diversity in sorghum (Grenier *et al.*, 2000).

According to Gebrekidan (1981), sorghum accessions with early flowering, early maturity and short plant height are most suitable for lowland areas with a limited rain fall and short growing season. Similarly, in the current study, sorghum accessions from the drought prone areas of Tigray were characterized by early flowering and early maturity, short plant height, small number of leaves per plant and small leaf area.

This result is also in agreement with the previous study in the region by Ayana and Bekele (1998) particularly for maturity and plant height. Therefore, there is a high possibility for obtaining important genes for these characters from the region. Moreover, accessions from Gamo Gofa and Wello gave relatively the higher grain yield per panicle than those from the rest of the regions. In the present study, most of the early maturing accessions from all regions of origins escaped post flowering moisture stress.

Moreover, according to (Ejeta *et al.,* 1999), grain yield is one of the most important traits in evaluating sorghum accessions for pre flowering and post flowering moisture stress. In the present study, 100 accessions which gave better grain yield per panicle than the best performing standard check for drought were identified. Therefore, all these accessions should be further evaluated under more severe moisture stress areas to generate drought tolerant varieties.

7.1.2. Bivariate Analysis

Significant and positive phenotypic correlations were obtained for most of the qualitative characters considered in this study. The correlation that exists between different characters is very important in plant breeding program, because it helps in the identification of easily measured characters that could be used as indicators of the more important and complex characters (Ayana and Bekele, 1998). Furthermore, high correlation coefficients between characters show that the characters share common element of genetic control between genes.

The significant positive correlation between number of days for 50% flowering, leaf number, leaf area, plant height and number of days for maturity is in agreement with the result of the previous study (Ayana and Bekele, 1998). The significant positive correlation between number of days for 50% flowering and plant height as observed in the present study and in the previous studies (Zongo *et al.,* 1993, Ayana and Bekele, 1998) suggests that the transfer of genes for maturity and plant height into the farmers preferred cultivars would be successful.

7.1.3. Multivariate Analysis

7.1.3.1. Clustering of accessions

Grouping of Ethiopian sorghum germplasm accessions associated with drought by cluster analysis is very important to select the promising accession from different clusters for crossing. Categorizing germplasm accessions into morphologically similar groups is useful for selecting parents for crossing. Therefore, to develop best sorghum variety for drought prone areas of the world through successive crossing, the identification of the appropriate parent genotype is vital.

The multivariate analysis based on quantitative traits grouped the accessions into different phenotypic diversity classes. Accessions within a cluster are assumed to be more closely related to each other in terms of the trait under consideration than those accessions in different clusters. Many early flowering and early maturing sorghum accessions with relatively short plant height from different regions were fallen in the same clusters. Moreover, as recognized during collection different sorghum cultivars preferred by farmers to give reasonable yield during the drought season were members of this cluster.

In this study, the contribution of most adaptive quantitative morphological characters such as plant height and number of days to 50% flowering and maturity in cluster analysis and principal component analysis is very high. In most cases, many accessions from the same collection area were also clustered together. However, a number of accessions collected from different regions were clustered together.

The previous studies reported using quantitative and qualitative data supports the absence of clear grouping of accessions based on geographical origin (Ayana and Bekele, 1999, Teshome *et al.*, 1997). Furthermore, according to Ayana and Bekele (1998), the morphological variation in the sorghum accessions is strongly influenced by environmental factors than region of origins.

In principal component analysis, the first four principal components, explained 62.09 % of the total variation among the accessions for thirteen quantitative traits. Moreover, some characters have greater importance in determining the existing variability than others. In the present study, leaf length, days to 50% flowering, plant height, leaf area and days to maturity were the most important traits contributing to the fist principal components.

Crossing of accessions belonging to different clusters of wide Mahalanobis distance (D^2) maximize the opportunity for transgressive segregation. In the current study, maximum genetic distances were obtained between C_7 and C_8, C_4 and C_8 and C_6 and C_7 with D^2 190.78, 160.95 and 147.98, respectively. However C_1 didn't show significant difference with C_2, C_3, C_4 and C_5. According to Zhong and Qualset (1995), maximum genetic recombination and variation in subsequent generation is expected from crosses that involve parents from those clusters characterized by maximum genetic distance. Therefore, crosses between sorghum accessions selected from those clusters with maximum D^2 are expected to provide relatively better genetic recombination and segregation in their progenies.

Furthermore, the selection of individual parents from such clusters must consider the special advantage of each cluster. A given sorghum accessions to be considered as a parent, in addition to genetic diversity, should express the optimum level of desired traits. Therefore, in this study those accessions which perform best in both location in the presence of various degree of moisture stress, after further selection in more severe moisture stressed areas, can be considered as a parent for crossing to generate drought tolerant variety if they are found in different clusters with maximum genetic distance.

7.2. Qualitative traits

7.2.1. Distribution of Qualitative Characters

The percentage frequency distribution of the phenotypic classes for each qualitative trait was analyzed across all regions of origins. All qualitative characters exhibited high diversity in their patterns of distribution and amount of variation. Except in a very few cases, for all regions the similar phenotypic class was abundant for all qualitative traits. In all regions, the dominant phenotypic classes were awned sorghum accessions with, compact and semi-compact elliptic panicle with exerted inflorescence, white leaf midrib color and white grain colour.

The highest frequency of awned sorghum accessions were obtained from Wello, Harerge and Tigray collections with 75%, 75% and 69%, respectively. For Wello collection, the result of the current study is in agreement with the previous study in the region by Abdi *et al., (*2002), where 75% of the 34 landraces were detected to have awns.

From a total of eleven phenotypic classes considered for panicle compactness and shape, the semi compact elliptic and the compact elliptic panicles were 47 % and 26%, respectively. Ayana and Bekele (1998) also reported that the compact and semi-compact panicles were more frequent in relatively hot and dry regions of Ethiopia such as Tigray, Wello and Harerge. White grain color accessions were also the most frequent phenotypic class for all regions of origins. Similarly, in the previous study, white seed color increases from highlands to lowlands (Ayana and Bekele, 1998).

7.2.2. Estimation of Genetic Diversity

The amount of phenotypic diversity between the accessions and their regions of origin were estimates based on Shannon-Weaver diversity index (H′). All the qualitative characters showed high diversity in their distribution as well as the amount of variation. The overall high phenotypic diversity index among accessions (H′=0.82) obtained in this study is in agreement with the result obtained in the previous study (Ayana and Bekele, 1998 and Abdi *et al.,* 2002).

The partitioning of the phenotypic diversity into within and between regions of origins indicates that a larger proportion of the total diversity was obtained within regions of origin than between regions of origin. About 87% of the total variation was found within regions of origin, while only 13% was found between regions of origin. Awn and waxy bloom took the highest share for phenotypic variation within regions of origin contributing 99% and 93%, respectively. Grain colour and panicle compactness and shape contributed relatively high regional differentiation, 23% and 24%, respectively. This result suggested that the existence of very high genetic diversity between accesions within each region of origin. Therefore, more collection within regions of origin is more advantageous for sorghum improvement program and genetic resource conservation.

8. Conclusions and Recommendation

Estimation of genetic diversity is very important in the evaluation of germplasm accessions to identify potential accessions as possible source of genes for a given trait of interest, for example drought resistance/tolerance. Currently, there is an increased interest both nationally and internationally in the utilization of different sorghum accessions adapted to drought. Therefore, it is indispensable to assess the degree of genetic diversity that exist among sorghum accessions associated with drought without excluding the fact that variability alone can not be taken as a guarantee for improvement unless they possess the trait of interest. This study has shown the existence of very high diversity among Ethiopian sorghum germplasm accessions collected from the drought prone areas based on quantitative and qualitative morphological traits.

Moreover, the accessions displayed a wide range of variation for various degree of moisture stress during their growth and development period. A number of accessions totally failed to withstand the post flowering moisture stress. Many early maturing sorghum accessions from all regions of origins escaped the post flowering moisture stress and gave better record for all morphological traits. Based on their field performance and grain yield per panicle, 95 and 100 sorghum accessions, respectively, were identified for further evaluation under more severe moisture stress areas.

Another outcome of this study was the understanding of the genetic relationship among the accessions which give an insight on which accessions to focus for crossing based on desirable morphological traits. Clustering of the accessions based on quantitative traits produced eight diversity classes. Many early flowering and early maturing sorghum accessions with relatively short plant height from different regions fall in the same clusters together with many farmers preferred cultivars. Maximum genetic distances were obtained between C_7 & C_8, C_4 & C_8, and C_6 & C_7 with D^2 190.78, 160.95 and 147.98 respectively. In any crop, crosses among parents with maximum genetic distances are more responsive to improvement for a given trait of interest; therefore there is a high possibility to get a number of promising parents from these clusters based on desirable quantitative and qualitative traits.

Moreover, all the qualitative characters displayed high diversity in their distribution as well as the amount of variation. The partitioning of the phenotypic diversity into within and between regions of origins also indicates that a larger proportion of the total diversity exists within regions of origin than between regions of origin.

Therefore, the Bio-EARN project and the National Sorghum Improvement Programme of Ethiopia can use all these information for various future activities to develop better drought resistant/tolerant varieties in the region. Although genetic diversity study using the quantitative and qualitative traits remain an effective method, morphological comparisons have some limitations including the influence of environment, subjectivity in the character evaluation and management practice. Therefore, further genetic diversity study is needed with appropriate molecular markers such as SSR (Simple Sequence Repeat) to precisely estimate the genetic diversity among the accessions.

Furthermore, to develop drought tolerant sorghum variety, based on morphological and molecular genetic diversity, highly homogenous but contrasting parents for traits related to drought tolerance should be crossed to produce the F_1 population which will be used to generate recombinant inbred lines (RILs) as a mapping population. Using these recombinant inbred line (RIL) mapping populations, QTLs conferring stay-green in sorghum germplasms accessions should be identified and marker assisted selection (MAS) should be used for introgression of QTLs conferring stay-green into farmers preferred sorghum varieties.

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10. Appendices

Appendix 1. Lists of sorghum accessions, collection area (Origin) and altitude of collection site of sorghum germplasms used in the study.

* No	Acces. No	Origin	Altitude	No	Acces. No	Origin	Altitude	No o	Acces. No	Origin	Altitude
1	Sorcoll-001/07	Tigray	1440	34	Sorcoll-036/07	Tigray	1665	67	Sorcoll-076/07	Tigray	1555
2	Sorcoll-002/07	Tigray	1440	35	Sorcoll-037/07	Tigray	1665	68	Sorcoll-077/07	Tigray	1555
3	Sorcoll-003/07	Tigray	1440	36	Sorcoll-038/07	Tigray	1665	69	Sorcoll-078/07	Tigray	1555
4	Sorcoll-004/07	Tigray	1400	37	Sorcoll-039/07	Tigray	1665	70	Sorcoll-079/07	Tigray	1555
5	Sorcoll-005/07	Tigray	1450	38	Sorcoll-040/07	Tigray	1700	71	Sorcoll-080/07	Tigray	1555
6	Sorcoll-006/07	Tigray	1480	39	Sorcoll-041/07	Tigray	1700	72	Sorcoll-081/07	Tigray	1555
7	Sorcoll-007/07	Tigray	1480	40	Sorcoll-044/07	Tigray	1375	73	Sorcoll-082/07	Tigray	1555
8	Sorcoll-008/07	Tigray	1480	41	Sorcoll-045/07	Tigray	1375	74	Sorcoll-083/07	Tigray	1555
9	Sorcoll-009/07	Tigray	1480	42	Sorcoll-046/07	Tigray	1375	75	Sorcoll-084/07	Tigray	1555
10	Sorcoll-011/07	Tigray	1450	43	Sorcoll-047/07	Tigray	1375	76	Sorcoll-085/07	Tigray	1555
11	Sorcoll-012/07	Tigray	1640	44	Sorcoll-048/07	Tigray	1375	77	Sorcoll-086/07	Tigray	1555
12	Sorcoll-013/07	Tigray	1640	45	Sorcoll-049/07	Tigray	1375	78	Sorcoll-087/07	Tigray	1555
13	Sorcoll-014/07	Tigray	1640	46	Sorcoll-050/07	Tigray	1375	79	Sorcoll-088/07	Tigray	1555
14	Sorcoll-015/07	Tigray	1645	47	Sorcoll-051/07	Tigray	1375	80	Sorcoll-089/07	Tigray	1600
15	Sorcoll-016/07	Tigray	1645	48	Sorcoll-052/07	Tigray	1375	81	Sorcoll-090/07	Tigray	1600
16	Sorcoll-017/07	Tigray	1645	49	Sorcoll-053/07	Tigray	1450	82	Sorcoll-091/07	Tigray	1600
17	Sorcoll-018/07	Tigray	1645	50	Sorcoll-054/07	Tigray	1450	83	Sorcoll-093/07	Tigray	1600
18	Sorcoll-019/07	Tigray	1645	51	Sorcoll-055/07	Tigray	1450	84	Sorcoll-094/07	Tigray	1600
19	Sorcoll-020/07	Tigray	1645	52	Sorcoll-056/07	Tigray	1450	85	Sorcoll-095/07	Tigray	1600
20	Sorcoll-021/07	Tigray	1645	53	Sorcoll-058/07	Tigray	1450	86	Sorcoll-096/07	Tigray	1600
21	Sorcoll-022/07	Tigray	1645	54	Sorcoll-060/07	Tigray	1450	87	Sorcoll-097/07	Tigray	1600
22	Sorcoll-023/07	Tigray	1645	55	Sorcoll-061/07	Tigray	1450	88	Sorcoll-098/07	Tigray	1600
23	Sorcoll-024/07	Tigray	1645	56	Sorcoll-062/07	Tigray	1450	89	Sorcoll-099/07	Tigray	1600
24	Sorcoll-026/07	Tigray	1570	57	Sorcoll-063/07	Tigray	1450	90	Sorcoll-100/07	Tigray	1600
25	Sorcoll-027/07	Tigray	1570	58	Sorcoll-065/07	Tigray	1450	91	Sorcoll-101/07	Tigray	1700
26	Sorcoll-028/07	Tigray	1570	59	Sorcoll-066/07	Tigray	1450	92	Sorcoll-102/07	Tigray	1700
27	Sorcoll-029/07	Tigray	1570	60	Sorcoll-068/07	Tigray	1450	93	Sorcoll-103/07	Tigray	1700
28	Sorcoll-030/07	Tigray	1570	61	Sorcoll-070/07	Tigray	1450	94	Sorcoll-104/07	Tigray	1700
29	Sorcoll-031/07	Tigray	1560	62	Sorcoll-071/07	Tigray	1555	95	Sorcoll-107/07	Tigray	1700
30	Sorcoll-032/07	Tigray	1440	63	Sorcoll-072/07	Tigray	1555	96	Sorcoll-108/07	Tigray	1700
31	Sorcoll-033/07	Tigray	1440	64	Sorcoll-073/07	Tigray	1555	97	Sorcoll-110/07	Tigray	1700
32	Sorcoll-034/07	Tigray	1440	65	Sorcoll-074/07	Tigray	1555	98	Sorcoll-111/07	Tigray	1700
33	Sorcoll-035/07	Tigray	1665	66	Sorcoll-075/07	Tigray	1555	99	Sorcoll-112/07	Tigray	1700

Appendix 1. Continued…

No	Acces. No	Origin	Altitude	No	Acces. No	Origin	Altitude	No	Acces. No	Origin	Altitude
100	Sorcoll-113/07	Tigray	1700	133	Sorcoll-152/07	Wello	1700	166	Sorcoll-195/07	Wello	1400
101	Sorcoll-114/07	Tigray	1700	134	Sorcoll-153/07	Wello	1700	167	Sorcoll-197/07	Wello	1400
102	Sorcoll-115/07	Tigray	1700	135	Sorcoll-154/07	Wello	1700	168	Sorcoll-198/07	Kemise	1400
103	Sorcoll-116/07	Tigray	1600	136	Sorcoll-155/07	Wello	1700	169	Sorcoll-200/07	Kemise	1335
104	Sorcoll-117/07	Tigray	1600	137	Sorcoll-156/07	Wello	1700	170	Sorcoll-201/07	Kemise	1335
105	Sorcoll-119/07	Tigray	1600	138	Sorcoll-159/07	Wello	1680	171	Sorcoll-202/07	Kemise	1400
106	Sorcoll-120/07	Tigray	1600	139	Sorcoll-160/07	Wello	1500	172	Sorcoll-203/07	Kemise	1400
107	Sorcoll-123/07	Wello	1550	140	Sorcoll-161/07	Wello	1500	173	Sorcoll-206/07	Kemise	1400
108	Sorcoll-124/07	Wello	1550	141	Sorcoll-162/07	Wello	1500	174	Sorcoll-207/07	Kemise	1400
109	Sorcoll-125/07	Wello	1550	142	Sorcoll-163/07	Wello	1500	175	Sorcoll-208/07	Kemise	1400
110	Sorcoll-127/07	Wello	1550	143	Sorcoll-164/07	Wello	1500	176	Sorcoll-210/07	Kemise	1400
111	Sorcoll-128/07	Wello	1550	144	Sorcoll-165/07	Wello	1500	177	Sorcoll-211/07	Kemise	1400
112	Sorcoll-130/07	Wello	1550	145	Sorcoll-166/07	Wello	1500	178	Sorcoll-213/07	Kemise	1400
113	Sorcoll-131/07	Wello	1550	146	Sorcoll-167/07	Wello	1500	179	Sorcoll-214/07	Kemise	1400
114	Sorcoll-132/07	Wello	1400	147	Sorcoll-168/07	Wello	1500	180	Sorcoll-215/07	Kemise	1400
115	Sorcoll-134/07	Wello	1400	148	Sorcoll-169/07	Wello	1500	181	Sorcoll-216/07	Kemise	1400
116	Sorcoll-135/07	Wello	1400	149	Sorcoll-173/07	Wello	1420	182	Sorcoll-217/07	Kemise	1400
117	Sorcoll-136/07	Wello	1400	150	Sorcoll-174/07	Wello	1420	183	Sorcoll-219/07	Kemise	1400
118	Sorcoll-137/07	Wello	1700	151	Sorcoll-175/07	Wello	1420	184	Sorcoll-220/07	Kemise	1400
119	Sorcoll-138/07	Wello	1700	152	Sorcoll-176/07	Wello	1420	185	Sorcoll-223/07	Shewa	1300
120	Sorcoll-139/07	Wello	1700	153	Sorcoll-177/07	Wello	1420	186	Sorcoll-224/07	Shewa	1300
121	Sorcoll-140/07	Wello	1700	154	Sorcoll-178/07	Wello	1420	187	Sorcoll-226/07	Shewa	1300
122	Sorcoll-141/07	Wello	1700	155	Sorcoll-179/07	Wello	1420	188	Sorcoll-227/07	Shewa	1300
123	Sorcoll-142/07	Wello	1700	156	Sorcoll-180/07	Wello	1420	189	Sorcoll-228/07	Shewa	1300
124	Sorcoll-143/07	Wello	1700	157	Sorcoll-181/07	Wello	1420	190	Sorcoll-229/07	Shewa	1300
125	Sorcoll-144/07	Wello	1700	158	Sorcoll-182/07	Wello	1420	191	Sorcoll-230/07	Shewa	1300
126	Sorcoll-145/07	Wello	1700	159	Sorcoll-183/07	Wello	1420	192	Sorcoll-231/07	Shewa	1300
127	Sorcoll-146/07	Wello	1700	160	Sorcoll-184/07	Wello	1420	193	Sorcoll-232/07	Shewa	1300
128	Sorcoll-147/07	Wello	1700	161	Sorcoll-185/07	Wello	1420	194	Sorcoll-234/07	Shewa	1300
129	Sorcoll-148/07	Wello	1700	162	Sorcoll-188/07	Wello	1420	195	Sorcoll-235/07	Shewa	1300
130	Sorcoll-149/07	Wello	1700	163	Sorcoll-189/07	Wello	1420	196	Sorcoll-236/07	Shewa	1300
131	Sorcoll-150/07	Wello	1700	164	Sorcoll-190/07	Wello	1400	197	Sorcoll-238/07	Shewa	1300
132	Sorcoll-151/07	Wello	1700	165	Sorcoll-194/07	Wello	1400	198	Sorcoll-239/07	Shewa	1300

Appendix 1. Continued…

No	Acces. No	Origin	Altitude	No	Acces. No	Origin	Altitude	No	Acces. No	Origin	Altitude
199	Sorcoll-240/07	Shewa	1300	231	Acc. No 239149	Wello	1560	265	Acc. No 238439	Tigray	800
200	Sorcoll-242/07	Shewa	1300	232	Acc. No 225837	Gamo Gofa	1510	266	Acc. No 235608	Gamo Gofa	1260
201	Sorcoll-243/07	Shewa	1300	233	Acc. No 239173	Wello	1560	267	Acc. No 69239	Harerge	1480
202	Sorcoll-244/07	Shewa	1300	234	Acc. No 239233	Wello	1560	268	Acc. No 241719	Gamo Gofa	1510
203	Sorcoll-245/07	Shewa	1300	235	Acc. No 241692	Harerge	1560	269	Acc. No 239191	Kemise	1560
204	Sorcoll-246/07	Shewa	1300	236	Acc. No 238420	Tigray	1560	270	Acc. No 239169	Kemise	1560
205	Sorcoll-247/07	Shewa	1300	237	Acc. No 238432	Tigray	1560	271	Acc. No 239167	Kemise	1560
206	Sorcoll-248/07	Shewa	1300	238	Acc. No 237311	Tigray	1560	273	Acc. No 237278	Tigray	1520
207	Sorcoll-249/07	Shewa	1300	239	Acc. No 237308	Tigray	1560	274	Acc. No 210919	Harerge	1560
208	Sorcoll-250/07	Shewa	1350	240	Acc. No 241689	Harerge	1560	275	Acc. No 235619	Gamo Gofa	1600
209	Sorcoll-251/07	Shewa	1350	241	Acc. No 237289	Tigray	1560	276	Acc. No 235928	Gonder	750
210	Sorcoll-253/07	Shewa	1350	242	Acc. No 239192	Wello	1560	277	Acc. No 239182	Kemise	1560
211	Sorcoll-254/07	Shewa	1350	243	Acc. No 238422	Tigray	1560	278	Acc. No 239251	Kemise	1600
212	Sorcoll-255/07	Shewa	1350	244	Acc. No 225840	Gamo Gofa	1510	279	Acc. No 239243	Kemise	1510
213	Sorcoll-256/07	Shewa	1400	245	Acc. No 239202	Welo	1560	280	Acc. No 241256	Harerge	1540
214	Sorcoll-257/07	Shewa	1400	246	Acc. No 69191	Harerge	1510	281	Acc. No 241281	Harerge	1510
215	Sorcoll-258/07	Shewa	1400	247	Acc. No 235605	Gamo Gofa	1250	282	Acc. No 239180	Kemise	1560
216	Sorcoll-259/07	Shewa	1400	248	Acc. No 210918	Gamo Gofa	1560	283	Acc. No 69187	Harerge	1560
217	Sorcoll-260/07	Shewa	1400	249	Acc. No 235607	Gamo Gofa	1260	285	Acc. No 239164	Kemise	1560
218	Sorcoll-262/07	Shewa	1400	250	Acc. No 241720	Gamo Gofa	1460	286	Acc. No 213027	Gamo Gofa	1400
219	Sorcoll-263/07	Shewa	1400	251	Acc. No 237283	Tigray	1560	287	Acc. No 239179	Kemise	1560
220	Sorcoll-269/07	Shewa	1400	253	Acc. No 2384400	Tigray	800	288	Acc. No 213022	Gamo Gofa	1600
221	Sorcoll-270/07	Shewa	1400	254	Acc. No 237261	Tigray	1250	289	Acc. No 239181	Kemise	1560
222	Sorcoll-271/07	Shewa	1100	255	Acc. No 69083	Gamo Gofa	1460	290	Acc. No 241706	Gamo Gofa	1410
223	Sorcoll-272/07	Kemise	1100	256	Acc. No 235924	Gonder	910	291	Acc. No 237286	Tigray	1500
224	Sorcoll-273/07	Kemise	1100	257	Acc. No 237267	Tigray	1460	292	Acc. No 69186	Harerge	1520
225	Sorcoll-274/07	Kemise	1100	258	Acc. No 213028	Gamo Gofa	1400	293	Acc. No 239177	Kemise	1560
226	Sorcoll-275/07	Kemise	1100	259	Acc. No 241716	Gamo Gofa	1510	294	Acc. No 235464	Tigray	1500
227	Sorcoll-276/07	Kemise	1100	260	Acc. No 225836	Gamo Gofa	1270	295	Acc. No 239228	Kemise	1580
228	Sorcoll-277/07	Kemise	1100	261	Acc. No 237275	Tigray	1570	296	Acc. No 239227	Kemise	1580
229	Sorcoll-278/07	Kemise	1100	262	Acc. No 225839	Gamo Gofa	1270	297	Acc. No 238426	Tigray	1080
230	Sorcoll-279/07	Kemise	1100	263	Acc. No 237287	Tigray	1100				

Appendix 1. Continued…

No	Acces. No	Origin	Altitude	No	Acces. No	Origin	Altitud	No	Acces. No	Origin	Altitude
298	Acc. No 239218	Kemise	1580	331	Acc. No 238447	Tigray	710	364	Acc. No 239174	Kemise	1560
299	Acc. No 241289	Harerge	1430	332	Acc. No 241709	Gamo Gofa	1530	365	Acc. No 239175	Kemise	1560
300	Acc. No 239225	Wello	1580	333	Acc. No 239197	Wello	1580	366	Acc. No 241712	Gamo Gofa	1520
301	Acc. No 241290	Harerge	1480	334	Acc. No 239201	Wello	1580	367	Acc. No 238429	Tigray	1050
302	Acc. No 237288	Tigray	1430	335	Acc. No 238401	Tigray	1460	368	Acc. No 241728	Tigray	1350
303	Acc. No 239223	Kemise	1580	336	Acc. No 241717	Gamo Gofa	1510	369	Acc. No 204608	Gamo Gofa	1490
304	Acc. No 239162	Kemise	1560	337	Acc. No 241727	Gamo Gofa	1360	370	Acc. No 238440	Tigray	760
305	Acc. No 237265	Tigray	1550	338	Acc. No 239198	Wello	1580	371	Acc. No 241226	Harerge	1550
306	Acc. No 234095	Tigray	1460	339	Acc. No 231208	Harerge	1550	372	Acc. No 239199	Kemise	1580
307	Acc. No 239196	Kemise	1580	340	Acc. No 212644	Wello	1540	373	Acc. No 239221	Kemise	1580
308	Acc. No 69506	Gamo Gofa	1450	341	Acc. No 238425	Tigray	1110	374	Acc. No 238402	Tigray	1460
309	Acc. No 234098	Tigray	1090	342	Acc. No 238424	Tigray	1110	375	Acc. No 239163	Wello	1560
310	Acc. No 239232	Wello	1470	343	Acc. No 234071	Tigray	1550	376	Acc. No 240807	Gamo Gofa	1600
311	Acc. No 237262	Wello	1600	344	Acc. No 239206	Wello	1580	377	Acc. No 69178	Gamo Gofa	1560
312	Acc. No 237274	Tigray	1450	345	Acc. No 210921	Harerge	1510	378	Acc. No 235461	Tigray	1500
313	Acc. No 237284	Tigray	1450	346	Acc. No 210920	Harerge	1600	379	Acc. No 234072	Tigray	1370
314	Acc. No 204612	Gamo Gofa	1400	347	Acc. No 235466	Tigray	1460	380	Acc. No 213005	Gamo Gofa	1240
315	Acc. No 235623	Gamo Gofa	1500	348	Acc. No 241690	Harerge	1490	381	Acc. No 238443	Tigray	700
316	Acc. No 239238	Wello	1510	349	Acc. No 241279	Harerge	1560	382	Acc. No 231193	Harerge	1500
317	Acc. No 234097	Tigray	1100	350	Acc. No 231192	Harerge	1540	383	Acc. No 239161	Wello	1560
318	Acc. No 237282	Tigray	1560	351	Acc. No 237269	Tigray	1550	384	Acc. No 239187	Wello	1560
319	Acc. No 238428	Tigray	1050	352	Acc. No 239237	Wello	1470	385	Acc. No 69513	Gamo Gofa	1600
320	Acc. No 217705	Gamo Gofa	1380	353	Acc. No 239236	Wello	1470	386	Acc. No 241288	Harerge	1220
321	Acc. No 237263	Wello	1470	354	Acc. No 239235	Wello	1470	387	Acc. No 239190	Wello	1560
322	Acc. No 239240	Wello	1510	355	Acc. No 239234	Wello	1470	388	Acc. No 241710	Gamo Gofa	1500
323	Acc. No 237266	Wello	1500	356	Acc. No 228831	Wello	1470	389	Acc. No 69084	Gamo Gofa	1500
324	Acc. No 69189	Harerge	1510	357	Acc. No 241694	Harerge	1480	390	Acc. No 239186	Wello	1560
325	Acc. No 239222	Wello	1580	358	Acc. No 239205	Wello	1580	391	Acc. No 239204	Wello	1580
326	Acc. No 239166	Wello	1560	359	Acc. No 239207	Wello	1580	392	Acc. No 239158	Tigray	1560
327	Acc. No 241711	Gamo Gofa	1500	360	Acc. No 241723	Gamo Gofa	1350	393	Acc. No 234056	Wello	1570
328	Acc. No 235925	Gonder	960	361	Acc. No 238441	Tigray	710	394	Acc. No 235462	Tigray	1500
329	Acc. No 239203	Wello	1580	362	Acc. No 241725	Gamo Gofa	1350	395	Acc. No 239157	Wello	1560
330	Acc. No 225838	Gamo Gofa	1270	363	Acc. No 241722	Gamo Gofa	1350	396	Acc. No 242283	Wello	1560

Appendix 1. Continued…

o	Acces. No	Origin	Altitude	No	Acces. No	Origin	Altitude	No	Acces. No	Origin	Altitude
397	Acc. No 238421	Tigray	1500	430	Acc. No 237285	Tigray	1570	463	Acc. No 241186	Harerge	1570
398	Acc. No 235463	Tigray	1500	431	Acc. No 241287	Harerge	1220	464	Acc. No 202508	Harerge	1560
399	Acc. No 235617	Gamogof	1600	432	Acc. No 241185	Harerge	1600	465	Acc. No 241280	Harerge	1550
400	Acc. No 239171	Wello	1560	433	Acc. No 239242	Wello	1580	466	Acc. No 212172	Harerge	1550
401	Acc. No 239152	Wello	1560	434	Acc. No 69502	Gamo Gofa	1300	467	Acc. No 239184	Wello	1560
402	Acc. No 223247	Tigray	1500	435	Acc. No 210917	Gamo Gofa	1560	468	Acc. No 239189	Wello	1560
403	Acc. No 239153	Wello	1560	436	Acc. No 235465	Gamogof	1560	469	Acc. No 241227	Harerge	1440
404	Acc. No 239156	Wello	1560	437	Acc. No 235926	Gonder	930	470	Acc. No 69185	Harerge	1520
405	Acc. No 239155	Wello	1560	438	Acc. No 210905	Gamo Gofa	1540	471	Acc. No 242044	Tigray	1550
406	Acc. No 239168	Wello	1560	439	Acc. No 239147	Wello	1560	472	Acc. No 241718	Gamo Gofa	1510
407	Acc. No 239193	Wello	1560	440	Acc. No 239150	Wello	1560	473	Acc. No 238427	Tigray	1040
408	Acc. No 239194	Wello	1560	441	Acc. No 239151	Wello	1560	474	Acc. No 238448	Tigray	710
409	Acc. No 235467	Tigray	1400	442	Acc. No 239188	Wello	1560	475	Acc. No 238449	Tigray	710
410	Acc. No 235448	Tigray	1600	443	Acc. No 239160	Wello	1560	476	Acc. No 238450	Tigray	710
411	Acc. No 204605	Gamogof	1320	444	Acc. No 241726	Gamo Gofa	1350	477	Acc. No 239217	Wello	1580
412	Acc. No 235447	Tigray	1600	445	Acc. No 69498	Gamo Gofa	1250	478	Acc. No 235611	Gamo Gofa	1440
413	Acc. No 239170	Wello	1560	446	Acc. No 238445	Tigray	700	479	Acc. No 235615	Gamo Gofa	1500
414	Acc. No 239200	Wello	1580	447	Acc. No 238446	Tigray	710	480	Acc. No 241693	Harerge	1480
415	Acc. No 204603	Gamogof	1300	448	Acc. No 239185	Wello	1560	481	Acc. No 235927	Gonder	820
416	Acc. No 69505	Gamogof	1400	449	Acc. No 204611	Gamo Gofa	1400	482	Acc. No 241714	Gamo Gofa	1500
417	Acc. No 239176	Wello	1560	450	Acc. No 213008	Gamo Gofa	1450	483	Acc. No 235929	Gonder	620
418	Acc. No 241286	Harerge	1210	451	Acc. No 239183	Wello	1560	484	Acc. No 235930	Gonder	620
419	Acc. No 235618	Gamogof	1600	452	Acc. No 241282	Harerge	1490	485	Acc. No 213017	Gamo Gofa	1380
420	Acc. No 239195	Wello	1560	453	Acc. No 241708	Gamo Gofa	1410	486	Acc. No 239178	Wello	1560
421	Acc. No 239241	Wello	1510	454	Acc. No 204636	Gamo Gofa	1490	487	Acc. No 239165	Wello	1560
422	Acc. No 241199	Harerge	1600	455	Acc. No 204610	Gamo Gofa	1430	488	Acc. No 237264	Wello	1560
423	Acc. No 239145	Wello	1560	456	Acc. No 204637	Gamo Gofa	1220	489	Acc. No 204606	Gamo Gofa	1320
424	Acc. No 241183	Harerge	1320	457	Acc. No 239225	Wello	1560	490	Acc. No 242045	Tigray	1550
425	Acc. No 239144	Wello	1560	458	Acc. No 241715	Gamo Gofa	1510	491	Acc. No 239239	Wello	1510
426	Acc. No 69190	Harerge	1510	459	Acc. No 241707	Gamo Gofa	1410	492	Acc. No 238423	Tigray	1120
427	Acc. No 239208	Wello	1580	460	Acc. No 238442	Tigray	700	493	Acc. No 234096	Tigray	1550
428	Acc. No 239148	Wello	1560	461	Acc. No 241691	Harerge	1490	494	Acc. No 231209	Harerge	1550
429	Acc. No 239224	Wello	1580	462	Acc. No 241705	Gamo Gofa	1200	495	Acc. No 241184	Harerge	1360

*Notes: * Accessions listed from serial number 1-230 are new collection by the BIO-EARN Project team in 2007 and those accessions listed from serial number 231-495 are collections by Institute of Biodiversity Conservation (IBC)*

Appendix 2. The combined over location mean of 13 quantitative traits[@] for 277 Sorghum accessions evaluated under field condition at Melkasa and Dera

Serial No	Accession No	Quantitative Characters												
		LN [@]	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
1	Sorcoll-001/07	12.4	63.1	7.3	343.5	209.2	13.9	14.3	5.0	85.9	123.1	55.8	35.2	52.5
2	Sorcoll-002/07	13.6	61.5	8.1	371.0	155.7	8.3	10.4	5.1	90.9	126.1	62.8	34.5	29.8
3	Sorcoll-003/07	11.2	73.3	7.5	411.7	204.2	14.8	8.9	4.2	91.9	124.6	77.3	29.5	45.9
4	Sorcoll-004/07	12.7	72.9	7.2	392.1	246.7	16.9	18.6	6.1	86.9	126.1	53.3	32.1	43.6
5	Sorcoll-005/07	11.5	73.8	6.9	383.9	265.6	18.5	10.8	4.4	92.4	124.6	54.3	32.4	50.4
6	Sorcoll-006/07	12.0	71.2	7.2	388.5	249.7	17.1	19.1	6.8	87.9	125.6	59.3	32.4	62.3
7	Sorcoll-007/07	11.9	63.7	7.1	339.2	180.2	15.8	17.0	5.4	87.9	124.6	38.3	36.3	54.3
8	Sorcoll-008/07	11.1	68.6	7.0	362.5	185.7	16.1	13.1	4.8	87.4	125.1	65.8	31.2	38.7
9	Sorcoll-009/07	10.5	74.5	7.2	405.7	186.7	13.1	9.0	4.5	90.4	125.1	56.3	29.8	45.5
10	Sorcoll-011/07	11.4	75.7	7.8	443.1	173.7	10.5	13.1	5.5	92.9	127.6	67.8	25.9	43.2
11	Sorcoll-012/07	12.0	76.5	6.9	398.8	217.2	14.5	11.8	5.4	91.4	127.6	81.8	33.1	50.1
12	Sorcoll-013/07	12.4	73.3	7.5	409.4	211.2	18.8	13.4	4.7	91.4	125.1	65.3	27.9	49.4
13	Sorcoll-014/07	11.4	68.9	6.9	354.6	249.2	15.6	19.2	6.0	86.4	123.1	57.3	31.3	56.8
14	Sorcoll-015/07	11.3	74.2	7.5	418.7	304.2	21.2	24.1	7.2	87.9	123.1	68.8	37.5	55.8
15	Sorcoll-016/07	12.2	70.0	7.2	378.5	234.2	20.3	19.9	7.7	87.4	125.6	104.3	30.5	57.6
16	Sorcoll-017/07	13.0	66.8	7.5	368.7	207.7	16.1	10.0	4.6	87.4	125.1	66.8	29.8	53.0
17	Sorcoll-018/07	10.9	73.0	6.4	351.8	255.7	14.1	17.9	6.4	88.4	123.1	60.8	31.3	46.8
18	Sorcoll-019/07	12.9	72.5	7.4	408.3	221.7	12.2	19.0	7.7	90.9	127.6	61.3	34.5	67.2
19	Sorcoll-021/07	12.8	76.7	6.2	362.9	219.2	10.6	15.6	5.2	90.9	123.1	61.3	32.1	91.5
20	Sorcoll-022/07	13.6	75.1	6.9	389.3	217.2	12.1	12.8	5.2	90.4	123.1	74.3	29.7	90.2
21	Sorcoll-023/07	9.8	68.0	6.3	321.3	221.2	16.1	22.8	6.9	86.9	123.1	47.3	23.9	47.8
22	Sorcoll-024/07	10.6	69.0	7.0	358.5	233.7	21.6	19.0	5.3	96.9	125.6	60.3	25.2	50.5
23	Sorcoll-027/07	9.1	65.2	6.5	317.1	235.2	19.8	18.8	6.7	83.4	113.6	55.8	29.7	74.2
24	Sorcoll-029/07	11.4	78.5	7.2	429.4	270.7	17.4	24.2	6.6	86.9	123.1	63.3	32.4	89.1
25	Sorcoll-030/07	8.2	54.0	6.3	253.1	173.2	19.7	22.1	5.9	79.4	113.6	46.3	25.3	50.6
26	Sorcoll-031/07	11.1	59.6	7.0	308.0	224.7	17.2	26.3	7.4	82.9	113.6	62.8	34.6	63.6
27	Sorcoll-032/07	11.5	81.6	7.8	480.4	174.2	15.5	28.1	5.7	93.9	125.1	64.8	26.9	49.9
28	Sorcoll-033/07	10.4	72.8	7.1	387.1	272.2	20.4	24.3	8.0	89.9	127.6	66.8	34.0	71.9

Appendix 2. Continued…

Serial No	Accession No	Quantitative Characters												
		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
29	Sorcoll-034/07	9.6	61.0	7.4	336.4	168.7	13.5	17.2	6.4	78.9	123.1	39.3	23.2	66.0
30	Sorcoll-035/07	13.4	65.2	8.0	394.0	193.7	11.8	16.0	4.7	92.4	131.1	65.3	33.7	45.9
31	Sorcoll-036/07	13.6	65.8	7.8	380.8	167.6	17.1	18.9	4.6	87.8	117.5	87.4	40.6	41.0
32	Sorcoll-037/07	12.1	61.4	7.3	335.6	198.6	17.2	15.5	5.3	76.3	119.0	62.4	27.3	47.9
33	Sorcoll-038/07	12.4	66.9	8.0	400.6	236.1	14.3	21.0	6.3	87.3	121.0	53.4	33.3	56.2
34	Sorcoll-039/07	12.4	62.5	7.9	372.0	217.6	16.2	19.4	7.6	82.8	121.5	60.4	33.4	58.4
35	Sorcoll-040/07	12.3	70.4	9.2	489.0	183.1	13.2	34.4	7.5	92.8	149.0	76.9	26.0	54.4
36	Sorcoll-041/07	11.8	75.1	9.1	515.2	211.1	16.8	32.7	7.9	86.8	133.5	42.9	35.4	47.8
37	Sorcoll-045/07	11.5	66.1	6.7	327.6	242.6	22.9	23.8	8.8	86.3	117.5	74.9	39.1	74.1
38	Sorcoll-046/07	14.7	63.4	6.7	307.2	242.6	19.8	20.7	7.0	82.8	126.0	79.4	36.0	54.5
39	Sorcoll-048/07	14.6	80.5	7.5	453.5	280.6	19.2	17.2	11.5	85.3	149.0	55.9	33.0	49.0
40	Sorcoll-049/07	13.1	68.7	7.6	390.2	227.6	16.3	19.0	7.2	88.8	139.0	56.4	35.1	41.0
41	Sorcoll-050/07	13.0	68.7	7.8	395.2	239.1	13.2	15.1	6.5	89.3	133.5	86.4	29.8	39.5
42	Sorcoll-051/07	14.1	73.1	7.4	398.6	251.1	14.9	15.1	7.8	95.8	146.5	56.4	35.0	44.5
43	Sorcoll-052/07	12.2	72.6	7.1	382.8	227.6	16.9	19.3	7.6	86.3	127.0	60.9	32.7	41.4
44	Sorcoll-053/07	11.3	57.7	6.7	286.1	172.2	17.3	13.2	7.6	87.3	149.0	39.9	36.4	48.0
45	Sorcoll-055/07	13.5	67.6	6.6	328.0	254.6	14.3	14.7	8.9	94.8	149.0	69.9	28.8	53.0
46	Sorcoll-058/07	11.6	72.7	7.2	383.7	204.6	17.1	15.9	5.5	88.3	129.5	73.9	33.9	52.6
47	Sorcoll-061/07	12.1	68.1	7.1	354.5	224.6	18.2	17.0	4.9	88.3	132.0	59.4	30.2	54.4
48	Sorcoll-066/07	12.7	68.7	7.1	361.2	214.1	14.4	16.7	6.1	84.8	149.0	60.9	27.3	46.1
49	Sorcoll-068/07	12.8	71.6	6.7	353.0	214.6	16.8	10.3	5.8	97.3	149.0	66.9	31.2	49.0
50	Sorcoll-070/07	11.7	68.4	8.1	420.1	215.6	18.4	24.2	6.2	87.3	136.0	50.9	29.7	50.6
51	Sorcoll-071/07	11.9	72.1	7.6	411.3	221.1	20.6	25.3	6.1	87.8	129.5	61.9	30.9	39.4
52	Sorcoll-072/07	11.6	74.0	7.4	406.1	201.6	16.8	27.4	6.4	87.8	129.5	60.4	28.6	38.3
53	Sorcoll-075/07	12.7	62.4	8.4	385.4	184.6	16.5	18.8	6.5	87.8	131.0	64.4	37.8	49.6
54	Sorcoll-076/07	12.6	77.5	9.0	515.1	225.7	12.8	17.4	6.1	92.0	139.5	93.7	25.8	43.3
55	Sorcoll-077/07	12.2	68.2	7.4	361.9	235.2	14.8	18.4	5.5	91.0	136.5	69.7	26.8	32.5
56	Sorcoll-078/07	12.4	72.6	8.0	420.5	256.2	15.5	15.5	5.6	91.0	127.5	59.2	33.3	67.3
57	Sorcoll-079/07	12.9	59.7	8.3	375.1	180.2	14.6	15.1	5.3	91.0	130.0	85.7	22.8	42.7

Appendix 2. Continued…

Serial No	Accession No	Quantitative Characters												
		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
58	Sorcoll-080/07	13.4	75.2	7.2	386.9	265.7	17.8	7.9	5.8	97.5	149.5	58.7	30.9	58.5
59	Sorcoll-081/07	13.2	69.2	7.3	358.2	259.2	17.4	14.1	6.2	93.5	129.5	78.7	33.8	54.2
60	Sorcoll-083/07	12.8	70.8	7.6	387.6	226.2	13.6	8.5	5.1	101.0	149.5	80.7	22.8	25.2
61	Sorcoll-084/07	12.4	72.1	7.2	375.8	237.7	17.3	11.8	6.4	92.5	134.0	53.2	25.4	35.8
62	Sorcoll-086/07	11.9	76.2	9.5	526.2	207.7	13.7	22.3	11.8	82.0	127.5	78.2	20.0	32.9
63	Sorcoll-087/07	13.7	74.4	8.9	487.1	254.2	17.6	24.2	7.3	83.0	136.5	72.7	29.6	47.7
64	Sorcoll-091/07	14.0	71.5	8.4	435.8	226.2	14.4	9.0	6.5	99.5	149.5	56.7	28.0	56.4
65	Sorcoll-093/07	12.2	75.7	8.0	441.5	213.7	12.5	10.6	8.1	89.5	130.0	87.2	25.4	57.1
66	Sorcoll-094/07	13.7	74.1	7.8	414.9	256.2	13.2	12.3	6.5	96.5	142.0	53.2	30.1	61.8
67	Sorcoll-096/07	12.5	78.8	8.6	494.8	186.2	12.7	22.0	7.8	86.0	124.0	63.7	25.7	54.3
68	Sorcoll-097/07	12.3	75.1	9.5	514.3	234.7	18.2	24.5	8.9	88.5	130.5	62.7	35.8	54.0
69	Sorcoll-098/07	12.1	73.9	7.7	418.7	249.7	21.2	11.3	6.5	89.0	130.0	80.7	26.3	46.3
70	Sorcoll-099/07	12.9	76.1	9.6	539.2	203.2	14.8	18.3	7.2	88.0	130.0	76.7	26.5	57.0
71	Sorcoll-100/07	12.9	73.9	8.0	429.1	219.7	13.8	18.9	5.6	86.0	126.5	53.2	33.2	31.9
72	Sorcoll-102/07	13.2	76.0	7.0	382.7	292.2	19.2	11.5	6.6	89.5	134.5	82.2	27.0	46.3
73	Sorcoll-103/07	12.1	75.2	8.4	464.0	246.2	18.0	21.1	6.1	91.0	134.5	74.2	30.2	29.3
74	Sorcoll-107/07	12.7	80.0	7.6	436.3	278.7	15.6	9.6	6.4	96.0	147.0	69.2	26.3	66.1
75	Sorcoll-110/07	13.5	74.6	8.1	438.2	267.2	18.5	7.7	5.4	91.0	142.5	58.7	22.5	39.1
76	Sorcoll-111/07	14.3	68.8	7.8	390.8	248.2	14.5	9.7	5.8	93.5	141.5	48.2	28.2	62.1
77	Sorcoll-112/07	13.8	71.9	7.3	378.7	267.2	12.9	8.7	7.6	94.0	147.0	61.2	26.2	63.0
78	Sorcoll-115/07	12.5	79.1	8.0	454.4	192.7	12.1	18.9	4.3	89.0	134.9	35.9	24.2	32.6
79	Sorcoll-125/07	9.3	52.5	8.1	304.5	125.9	10.2	13.9	5.9	71.5	111.4	31.9	27.1	34.4
80	Sorcoll-127/07	11.6	74.1	7.6	399.5	238.2	11.4	12.9	6.2	85.0	140.9	55.4	31.4	64.7
81	Sorcoll-128/07	13.2	82.7	8.1	479.0	237.2	10.4	12.8	5.1	90.5	145.4	27.4	24.8	39.3
82	Sorcoll-132/07	9.1	49.6	6.8	255.8	78.2	11.7	18.1	7.3	73.5	111.9	25.4	33.3	45.9
83	Sorcoll-134/07	11.8	59.5	8.2	355.1	208.2	14.0	14.3	5.7	87.0	124.9	50.4	24.6	51.2
84	Sorcoll-135/07	13.5	64.8	7.3	338.0	227.7	16.4	14.4	5.7	95.5	130.9	68.4	32.4	41.8
85	Sorcoll-137/07	11.8	72.8	8.0	416.3	232.7	15.5	13.0	6.2	98.0	138.4	42.4	29.0	38.2
86	Sorcoll-140/07	11.7	71.7	7.3	375.8	239.7	14.8	11.1	4.2	87.5	138.4	70.4	30.7	40.4

Appendix 2. Continued…

Serial No	Accession No	Quantitative Characters												
		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
87	Sorcoll-143/07	12.4	71.9	7.1	359.0	226.7	14.9	10.0	4.6	91.5	145.4	59.4	28.9	62.2
88	Sorcoll-145/07	11.6	69.8	7.5	374.7	223.7	13.6	10.1	3.7	86.0	133.4	56.4	27.2	69.5
89	Sorcoll-147/07	13.5	76.8	9.4	522.8	190.2	11.9	17.6	5.8	97.5	140.4	46.9	31.7	66.6
90	Sorcoll-148/07	11.9	76.8	8.2	452.4	184.2	13.5	18.5	6.5	100.5	140.4	71.9	30.7	59.7
91	Sorcoll-149/07	12.8	77.4	7.7	428.5	261.7	14.4	14.6	6.4	106.0	147.9	64.9	35.1	50.9
92	Sorcoll-150/07	11.5	71.7	7.5	384.6	214.2	14.2	14.3	4.9	95.0	145.9	87.9	23.9	41.5
93	Sorcoll-151/07	10.5	72.0	9.3	488.7	156.7	13.4	9.4	5.6	88.0	133.4	50.9	26.2	34.9
94	Sorcoll-156/07	9.6	68.7	6.8	360.8	187.6	13.5	10.4	3.0	91.3	132.5	74.3	31.4	35.9
95	Sorcoll-161/07	10.1	70.5	7.0	380.7	184.1	15.4	10.6	4.2	88.8	136.5	63.3	29.8	28.3
96	Sorcoll-162/07	10.5	69.2	7.1	380.9	180.6	14.0	14.6	3.9	87.8	124.5	63.8	29.4	68.1
97	Sorcoll-163/07	11.3	76.0	9.7	574.3	220.1	14.2	17.2	5.7	88.8	136.5	52.3	38.3	52.8
98	Sorcoll-164/07	8.9	73.3	7.6	419.3	208.1	17.6	14.3	4.9	89.3	132.5	81.8	33.2	45.8
99	Sorcoll-165/07	8.3	63.3	7.6	373.6	205.4	15.8	19.3	4.8	82.8	133.0	62.8	35.0	55.9
100	Sorcoll-166/07	10.6	71.4	8.6	473.7	200.1	15.3	12.2	4.1	84.3	133.0	48.8	28.5	55.4
101	Sorcoll-167/07	10.3	74.6	7.1	401.2	201.6	15.4	9.8	3.6	85.8	133.5	66.8	29.9	39.6
102	Sorcoll-169/07	11.0	83.0	9.6	613.8	151.1	14.3	19.6	6.3	98.8	145.0	58.3	31.1	40.0
103	Sorcoll-176/07	12.0	74.9	7.2	413.5	241.8	17.9	14.5	5.8	106.8	152.5	29.3	34.7	91.5
104	Sorcoll-178/07	11.8	75.2	7.8	450.5	215.1	15.1	13.8	4.7	87.8	139.5	54.8	36.5	47.8
105	Sorcoll-179/07	10.6	69.4	8.0	434.2	267.1	15.7	21.0	5.2	106.8	152.5	64.3	28.6	59.4
106	Sorcoll-183/07	11.7	71.2	7.8	430.7	215.6	20.0	16.0	4.0	92.8	133.0	82.8	27.5	43.4
107	Sorcoll-185/07	8.6	69.7	8.1	435.9	221.7	23.9	17.4	5.2	95.8	133.0	36.3	31.1	59.4
108	Sorcoll-188/07	9.8	65.7	7.0	354.1	220.6	22.4	18.1	4.6	93.8	133.0	77.8	27.9	49.1
109	Sorcoll-194/07	11.3	69.3	7.0	371.7	206.1	12.5	20.8	5.2	98.3	148.0	52.8	36.9	56.9
110	Sorcoll-198/07	12.4	76.9	5.9	347.2	233.4	14.9	21.2	6.6	106.5	137.9	75.3	29.4	57.9
111	Sorcoll-203/07	13.4	75.1	6.5	380.3	247.9	12.6	22.8	7.4	118.0	140.4	68.8	27.2	48.0
112	Sorcoll-207/07	13.4	74.0	6.1	339.0	279.9	20.1	20.6	5.6	115.0	147.9	65.8	27.9	41.8
113	Sorcoll-214/07	12.8	85.0	6.3	408.0	226.4	12.9	22.2	5.9	117.0	139.9	67.3	29.8	62.7
114	Sorcoll-216/07	11.7	76.0	7.1	407.5	204.4	14.9	13.8	6.2	107.0	145.4	87.8	28.8	49.6
115	Sorcoll-217/07	14.2	73.0	6.7	371.4	249.9	14.9	11.4	5.5	112.5	140.4	80.3	29.0	37.5

Appendix 2. Continued…

Serial No	Accession No	Quantitative Characters												
		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
116	Sorcoll-226/07	9.9	65.6	5.3	266.9	218.9	17.2	8.7	4.6	92.5	130.9	67.8	27.5	36.0
117	Sorcoll-228/07	10.0	62.8	6.0	295.0	178.9	17.5	6.1	3.6	96.0	130.4	89.3	28.4	37.8
118	Sorcoll-229/07	12.0	71.0	6.0	324.4	197.4	16.6	13.4	4.5	93.0	126.4	95.3	33.4	39.0
119	Sorcoll-230/07	10.7	63.9	6.3	309.0	134.3	13.7	17.0	5.2	81.5	119.9	52.3	44.6	27.2
120	Sorcoll-231/07	10.7	62.6	6.6	306.7	172.4	13.6	15.6	5.2	78.0	119.4	64.3	33.9	44.4
121	Sorcoll-232/07	10.8	64.5	7.4	357.8	171.9	15.6	17.1	6.8	81.0	120.9	53.3	33.9	58.3
122	Sorcoll-239/07	10.7	67.7	6.1	305.7	188.9	16.2	14.0	5.4	81.0	132.9	51.8	33.4	47.3
123	Sorcoll-244/07	10.9	65.2	7.4	365.4	195.1	15.4	13.9	6.1	97.6	126.4	42.7	35.9	39.5
124	Sorcoll-246/07	13.7	86.2	7.3	485.0	250.6	16.2	14.6	7.9	97.6	150.9	76.2	24.7	18.7
125	Sorcoll-248/07	10.9	77.1	6.9	403.5	216.1	15.2	13.8	8.9	94.6	146.4	69.2	26.7	34.1
126	Sorcoll-250/07	10.8	68.2	7.2	380.8	160.6	18.5	16.9	6.5	84.1	126.4	37.7	35.6	27.1
127	Sorcoll-251/07	11.6	78.8	6.9	413.4	184.6	12.6	13.6	7.3	108.6	145.9	46.7	25.4	29.1
128	Sorcoll-254/07	12.0	73.8	7.1	328.4	176.7	10.8	12.3	6.7	108.6	153.4	59.7	22.4	32.8
129	Sorcoll-256/07	10.2	57.5	6.4	299.4	180.6	11.8	6.1	5.1	96.6	139.4	49.7	22.4	16.3
130	Sorcoll-258/07	12.2	78.4	7.8	462.3	214.6	17.9	16.8	8.7	90.6	140.4	67.7	26.4	66.4
131	Sorcoll-260/07	11.6	76.2	7.8	455.5	238.1	13.0	16.0	7.5	112.6	150.9	39.2	25.7	40.6
132	Sorcoll-272/07	9.1	68.9	8.6	450.6	182.6	17.0	19.7	7.2	86.1	123.4	62.2	28.0	57.8
133	Sorcoll-273/07	10.7	80.8	8.2	498.0	245.6	20.4	16.0	7.9	99.6	145.9	62.2	27.1	58.4
134	Sorcoll-274/07	12.1	80.6	7.3	448.5	229.4	20.0	17.0	8.4	99.6	142.9	84.7	21.4	63.0
135	Sorcoll-276/07	12.7	79.4	7.6	459.5	238.6	20.5	15.6	8.4	106.6	154.9	69.2	25.6	70.0
136	Sorcoll-277/07	11.1	75.8	7.4	424.2	246.6	27.4	12.9	5.7	91.6	135.4	38.7	29.6	27.1
137	Acc. No 237287	11.6	67.7	7.2	377.4	249.1	13.9	13.6	5.1	104.6	154.9	63.7	30.0	18.4
138	Acc. No 238432	10.1	65.8	5.4	274.1	227.5	22.0	25.2	9.0	85.5	123.8	74.8	30.8	51.9
139	Acc. No 238422	10.2	70.7	5.9	315.8	254.5	20.4	20.4	8.1	82.5	128.8	44.3	23.6	44.5
140	Acc. No 235605	13.3	75.3	5.7	333.8	253.0	17.4	13.6	6.2	96.0	140.8	37.3	28.8	49.3
141	Acc. No 210918	13.5	72.9	6.4	353.6	215.5	19.5	17.0	7.6	100.0	145.8	98.3	29.5	74.4
142	Acc. No 235607	11.6	72.2	6.7	374.0	178.5	14.5	13.2	5.8	81.0	122.8	58.8	28.9	74.0
143	Acc. No 241720	12.9	73.2	6.5	363.0	215.0	20.3	14.6	6.4	80.0	120.8	62.3	27.2	76.4

Appendix 2. Continued…

	Accession No	Quantitative Characters

Serial No		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
144	Acc.No 2384400	12.4	60.4	5.7	253.0	162.5	5.9	11.4	5.4	84.5	118.8	77.8	25.9	37.1
145	Acc. No 235924	12.0	80.5	6.1	382.6	193.0	10.9	15.5	7.7	107.5	145.8	70.8	23.5	54.7
146	Acc. No 237267	13.1	70.2	5.6	306.2	221.0	15.7	14.4	6.3	106.0	149.8	86.3	29.0	48.6
147	Acc. No 213028	12.4	67.7	6.2	307.9	240.5	15.6	16.1	7.3	115.5	140.8	41.3	21.1	69.1
148	Acc. No 241716	13.7	69.9	7.2	266.9	229.0	15.8	15.7	9.2	112.5	149.8	38.3	28.0	30.3
149	Acc. No 225836	14.8	87.4	6.9	469.7	219.5	13.7	17.6	12.1	110.5	148.3	47.3	23.7	54.6
150	Acc. No 237275	13.2	73.8	6.8	375.7	254.0	17.9	19.6	5.7	80.0	119.3	29.8	30.8	61.5
151	Acc. No 225839	14.2	87.2	7.6	513.3	221.0	13.1	13.9	6.9	112.0	140.8	53.8	26.4	58.7
152	Acc. No 238439	10.8	67.3	7.0	355.8	181.1	17.9	17.9	6.8	72.3	112.5	54.1	41.3	36.8
153	Acc. No 235608	11.1	71.4	8.8	474.4	235.6	14.3	13.5	6.1	95.8	139.0	61.1	27.2	78.4
154	Acc. No 241719	10.9	71.6	8.2	440.6	206.1	11.1	26.1	6.4	108.8	149.0	13.1	28.2	74.7
155	Acc. No 239191	11.6	72.6	9.5	519.0	292.6	15.0	19.0	7.4	108.8	149.0	64.6	24.6	55.8
156	Acc. No 239169	11.6	75.1	7.2	409.4	315.1	13.9	19.4	5.5	107.8	149.0	54.6	26.5	30.8
157	Acc. No 69510	12.2	74.1	8.1	456.1	283.1	14.9	19.0	7.1	105.8	149.0	46.1	22.3	73.4
158	Acc. No 237278	10.4	67.6	6.4	330.3	305.1	20.3	27.4	5.0	90.8	132.0	49.1	19.7	21.1
159	Acc. No 235619	11.1	75.9	6.5	372.7	290.1	15.8	17.5	5.2	107.3	150.1	21.6	27.8	48.9
160	Acc. No 235928	12.1	79.8	6.9	416.4	236.6	11.7	22.3	7.9	109.3	150.1	87.6	33.3	57.8
161	Acc. No 239243	12.1	68.6	8.2	427.6	186.1	14.5	9.2	6.0	88.8	124.0	57.1	32.9	50.8
162	Acc. No 241706	10.3	73.6	8.1	454.4	160.1	16.9	17.2	8.6	78.8	109.5	71.1	27.9	69.5
163	Acc. No 237286	11.7	66.6	7.3	368.3	209.6	19.1	19.1	5.3	91.8	150.5	79.6	29.5	32.1
164	Acc. No 235464	9.7	73.7	8.5	473.7	229.1	11.9	22.2	6.2	86.8	113.0	35.1	27.7	48.2
165	Acc. No 239227	10.0	73.6	7.3	414.2	245.6	18.6	15.7	9.6	92.8	146.5	49.1	23.7	45.7
166	Acc. No 238426	9.0	57.9	7.4	329.0	146.6	13.9	11.7	6.9	83.3	116.0	43.1	32.6	41.7
167	Acc. No 237288	10.5	78.9	7.4	432.1	294.9	23.5	24.9	4.7	84.3	123.5	49.4	34.4	50.9
168	Acc. No 237265	14.6	74.5	7.1	406.5	277.9	22.4	15.3	7.9	99.3	146.5	61.4	32.2	46.8
169	Acc. No 234095	10.0	69.2	6.5	339.4	234.4	22.6	26.0	6.2	76.3	133.5	47.9	34.0	64.6
170	Acc. No 69506	10.0	70.5	6.3	333.7	277.4	19.1	19.9	5.0	92.8	141.5	45.4	32.0	55.9
171	Acc. No 234098	8.9	67.2	7.6	386.8	169.9	13.0	14.0	5.0	76.3	124.0	36.4	36.7	34.3

Appendix 2. Continued…

Serial	Accession No	Quantitative Characters

No		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
172	Acc. No 239232	10.0	76.6	7.0	399.7	214.4	13.2	14.6	5.3	88.3	124.0	46.4	26.1	34.3
173	Acc. No 237274	11.8	73.7	6.9	375.5	260.4	19.2	16.7	6.7	83.8	126.5	60.4	39.7	56.6
174	Acc. No 237284	9.4	76.6	7.9	448.8	142.0	9.1	20.7	4.3	87.8	131.5	61.9	33.8	44.1
175	Acc. No 235623	11.6	74.5	6.3	356.1	298.9	14.3	19.5	4.7	106.8	76.5	62.4	30.2	58.0
176	Acc. No 239238	11.5	70.5	6.9	376.7	233.4	14.4	17.8	4.5	83.8	136.5	69.4	30.1	51.6
177	Acc. No 234097	10.4	69.8	6.5	340.0	162.7	28.2	20.7	5.4	79.8	129.0	51.4	30.4	47.4
178	Acc. No 237282	11.2	70.3	7.3	382.2	213.4	9.0	17.1	3.9	88.8	148.0	62.4	33.8	34.1
179	Acc. No 238428	8.4	62.8	6.5	310.6	187.9	17.2	17.4	5.1	74.8	112.0	57.9	32.3	44.3
180	Acc. No 217705	10.0	70.1	6.2	324.5	259.4	19.6	24.1	3.8	90.3	136.5	35.4	28.8	51.1
181	Acc. No 237263	11.2	68.3	6.5	331.5	261.4	16.0	16.5	4.2	86.3	133.5	32.9	41.4	23.5
182	Acc. No 239240	11.0	77.3	6.9	399.6	190.4	8.7	21.7	5.5	99.3	138.5	55.9	34.3	40.2
183	Acc. No 239222	10.8	71.1	8.4	439.1	368.4	16.8	25.0	5.3	103.8	141.5	51.9	26.6	67.7
184	Acc. No 239166	12.8	72.6	7.6	411.3	287.4	20.1	20.9	5.5	109.3	151.5	69.4	26.8	82.1
185	Acc. No 235925	10.0	62.2	6.1	286.1	214.9	17.7	16.9	3.8	83.3	133.5	50.9	40.9	41.3
186	Acc. No 238447	9.8	57.7	6.1	287.3	155.4	13.2	17.3	5.3	70.0	131.6	44.2	37.4	40.4
187	Acc. No 241709	12.3	71.4	7.8	426.1	270.9	14.3	18.9	6.8	95.5	131.6	22.2	35.0	84.8
188	Acc. No 239201	14.2	79.5	6.9	424.0	282.4	17.6	20.1	7.9	106.0	149.6	61.2	29.5	42.8
189	Acc. No 238401	11.9	75.8	7.6	442.5	255.4	15.0	19.3	7.0	82.0	119.6	65.2	48.4	64.4
190	Acc. No 241727	12.7	72.6	7.5	422.8	350.9	13.7	25.9	5.0	116.0	149.6	67.7	27.6	64.6
191	Acc. No 238425	10.9	64.8	5.6	289.7	246.9	20.8	30.0	6.9	80.0	119.6	77.2	26.3	62.3
192	Acc. No 238424	10.4	67.2	6.6	342.1	218.4	17.0	20.5	6.6	72.5	110.1	38.2	34.3	31.6
193	Acc. No 234071	12.4	66.1	7.0	366.6	261.4	8.6	20.9	5.4	89.0	127.6	42.2	32.6	36.1
194	Acc. No 239206	13.4	74.1	7.9	450.4	263.9	9.9	22.7	6.6	105.5	147.1	54.2	33.3	53.8
195	Acc. No 210921	14.6	76.0	7.1	410.3	273.9	12.2	12.3	7.7	113.5	147.1	55.2	36.8	44.5
196	Acc. No 210920	13.1	74.6	6.7	392.1	329.9	11.6	26.5	7.2	101.5	134.6	27.2	30.2	54.0
197	Acc. No 235466	11.7	62.4	6.5	318.1	215.4	8.2	19.9	8.1	90.5	134.6	41.2	25.3	54.4
198	Acc. No 241279	13.9	83.4	7.1	446.7	258.9	17.4	15.1	8.0	105.5	147.1	56.2	37.2	52.5
199	Acc. No 239237	11.0	58.6	6.3	304.9	213.4	21.6	22.5	8.2	71.0	109.6	75.2	24.9	58.6

Appendix 2. Continued…

	Accession No	Quantitative Characters

Serial No		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
200	Acc. No 239236	12.1	76.5	9.4	550.4	275.9	20.6	16.8	8.6	89.0	148.6	64.7	30.5	65.9
201	Acc. No 239234	13.7	76.2	7.9	459.0	262.4	21.8	21.2	8.1	85.5	121.6	54.7	35.2	104.8
202	Acc. No 241723	10.9	75.2	7.8	456.2	279.9	20.8	32.0	9.1	82.0	134.6	49.7	34.4	88.7
203	Acc. No 238441	10.2	65.8	7.3	400.1	182.4	13.2	19.7	7.6	76.0	112.1	36.2	31.2	85.3
204	Acc. No 241725	10.7	72.6	8.5	475.8	218.4	19.6	21.5	6.6	78.0	112.1	45.7	37.4	74.7
205	Acc. No 239174	13.8	79.5	7.5	458.7	263.6	21.5	17.3	8.1	109.1	146.6	115.7	29.9	112.2
206	Acc. No 241712	11.1	79.4	8.3	503.7	273.6	27.8	22.0	5.4	116.1	147.6	49.7	33.6	81.1
207	Acc. No 241728	10.8	68.2	7.5	397.5	313.6	23.7	14.4	14.1	90.1	124.1	43.2	36.3	70.1
208	Acc. No 239199	12.3	79.0	8.6	510.7	360.1	27.2	48.4	6.3	110.6	146.6	44.7	23.4	72.6
209	Acc. No 239221	11.8	77.4	8.9	538.3	330.6	20.9	20.1	6.8	116.6	155.6	67.2	27.8	66.5
210	Acc. No 238402	10.8	69.3	9.3	489.6	184.6	13.9	23.3	4.8	91.6	126.1	72.2	32.9	63.2
211	Acc. No 235461	11.1	73.2	8.8	489.4	233.6	14.4	18.3	5.1	85.1	132.1	38.7	30.7	49.5
212	Acc. No 234072	12.3	68.1	7.7	403.5	167.1	14.1	20.4	6.0	93.6	136.1	65.7	26.8	45.9
213	Acc. No 213005	13.6	72.3	8.4	469.3	210.6	14.2	22.3	5.7	113.6	154.1	50.7	26.9	70.3
214	Acc. No 238443	8.2	72.1	7.7	426.4	167.1	13.2	16.6	5.3	79.1	121.6	59.7	33.0	38.1
215	Acc. No 69513	12.2	73.4	5.8	335.6	340.6	19.5	21.3	4.8	100.1	144.1	24.7	27.7	38.4
216	Acc. No 241288	13.7	71.8	7.3	414.5	282.1	23.1	12.4	4.8	93.6	129.1	109.7	27.0	53.4
217	Acc. No 241710	9.5	65.4	6.6	352.4	172.1	17.7	17.3	5.5	92.6	129.6	55.2	23.3	48.2
218	Acc. No 69084	11.4	73.0	6.4	361.6	278.1	15.7	16.1	5.5	101.1	148.6	28.7	28.8	52.4
219	Acc. No 234056	13.7	82.3	9.1	569.5	309.6	18.1	17.6	6.6	113.6	154.1	46.7	28.4	78.9
220	Acc. No 235462	12.7	73.1	7.2	410.2	291.1	17.8	19.2	9.5	87.1	132.1	33.2	31.7	33.2
221	Acc. No 239157	13.6	85.0	8.4	537.4	271.6	21.9	13.2	6.2	110.6	149.1	46.2	25.6	70.5
222	Acc. No 238421	12.7	79.2	8.1	476.9	270.8	17.1	19.1	6.7	101.0	151.3	55.4	42.8	68.4
223	Acc. No 235463	11.5	70.1	6.7	349.0	268.8	19.3	23.8	5.6	78.5	127.8	67.9	37.7	60.6
224	Acc. No 239171	14.9	72.3	8.2	442.0	258.8	15.3	15.9	6.5	94.5	136.8	56.9	28.9	43.7
225	Acc. No 239152	13.8	81.4	6.8	413.9	317.1	16.8	19.8	9.2	110.5	149.8	80.9	30.0	81.7
226	Acc. No 239194	13.3	73.6	7.4	415.2	263.3	10.6	17.7	6.6	110.5	147.3	50.4	31.6	45.3
227	Acc. No 235467	11.6	75.5	7.7	434.1	188.8	9.6	19.4	6.6	84.5	127.8	38.4	31.9	36.7

Appendix 2. *Continued…*

Serial	Accession No	Quantitative Characters

No		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
228	Acc. No 235448	12.3	68.0	6.8	349.3	234.8	14.2	13.6	5.1	85.5	134.8	56.4	36.7	51.2
229	Acc. No 235447	12.5	70.2	7.1	377.6	215.8	13.4	15.2	4.5	100.5	144.8	60.4	32.6	44.1
230	Acc. No 69505	12.3	73.0	8.1	445.9	259.8	15.8	20.5	5.4	80.0	127.8	59.4	29.5	57.6
231	Acc. No 235618	11.8	70.9	7.9	418.9	247.4	19.2	23.0	5.9	110.5	149.8	24.4	30.6	70.2
232	Acc. No 239241	11.2	72.6	9.2	393.4	195.4	17.8	18.4	7.0	87.0	127.3	22.9	28.6	33.7
233	Acc. No 69190	12.8	76.5	7.3	424.1	311.8	29.3	22.4	8.4	107.0	83.8	84.4	31.0	56.9
234	Acc. No 239208	13.7	73.8	6.7	374.0	303.8	25.4	25.0	9.3	90.0	139.8	37.9	38.2	60.2
235	Acc. No 239224	13.2	71.5	8.4	449.4	324.3	17.4	32.0	5.2	117.0	151.3	69.4	26.5	99.7
236	Acc. No 237285	13.4	63.8	8.3	382.0	153.6	6.7	14.6	5.5	102.8	134.3	72.6	44.9	26.1
237	Acc. No 241287	14.7	72.5	8.2	429.3	255.1	18.9	12.0	3.5	115.3	141.3	58.1	35.0	39.2
238	Acc. No 239242	12.1	71.3	7.8	407.2	255.6	22.8	15.4	5.9	83.8	123.3	92.1	31.9	73.1
239	Acc. No 69502	13.1	75.0	7.7	423.5	261.6	18.5	20.0	4.3	108.8	148.8	42.6	22.5	107.2
240	Acc. No 210917	16.6	71.8	7.2	370.0	295.6	14.6	13.0	5.2	112.3	152.8	41.1	28.1	57.0
241	Acc. No 235926	11.7	73.2	8.6	459.4	203.1	17.6	18.0	6.3	100.8	133.8	53.1	30.7	40.6
242	Acc. No 210905	11.8	78.6	7.8	450.6	351.6	23.7	22.8	3.4	109.3	141.3	33.6	26.1	30.4
243	Acc. No 239188	14.0	81.4	6.6	398.0	294.1	13.4	8.9	4.7	117.8	148.8	47.6	27.5	45.6
244	Acc. No 241726	12.3	73.0	6.0	318.9	240.6	15.8	13.1	5.1	108.8	134.3	38.1	22.4	25.7
245	Acc. No 69498	11.4	74.3	8.1	438.8	208.1	11.0	18.4	6.0	114.3	141.3	45.1	25.4	54.5
246	Acc. No 238445	8.7	63.2	6.0	285.1	171.1	17.0	14.2	4.7	68.8	119.8	60.6	33.2	28.4
247	Acc. No 238446	8.0	56.5	6.1	252.4	163.1	13.2	13.5	4.7	68.3	119.8	33.6	34.3	26.8
248	Acc. No 204611	11.1	76.8	7.9	441.2	174.6	8.6	14.3	4.1	89.3	113.8	33.1	33.6	22.1
249	Acc. No 213008	11.2	81.3	8.2	481.9	159.1	11.4	16.9	4.5	92.3	136.3	21.1	27.3	42.6
250	Acc. No 204636	12.4	76.2	6.1	331.6	311.1	15.0	20.4	3.3	109.8	136.8	37.1	30.6	49.8
251	Acc. No 204610	12.2	76.6	7.4	410.2	344.1	15.2	23.0	3.9	87.8	131.3	71.1	29.7	42.6
252	Acc. No 204637	12.2	77.0	6.6	371.8	302.6	16.8	22.7	3.1	88.8	133.3	53.1	23.1	14.7
253	Acc. No 239225	14.1	79.7	7.5	424.4	301.1	16.6	8.0	4.4	115.3	148.8	59.1	26.6	44.8
254	Acc. No 241715	12.5	84.1	7.2	440.1	271.6	16.1	15.4	5.5	109.3	141.3	47.1	28.0	76.9
255	Acc. No 241707	13.4	77.2	8.3	470.2	300.1	9.6	18.0	4.1	115.3	148.8	16.1	26.1	63.8

Appendix 2. Continued…

Serial No	Accession No	Quantitative Characters												
		LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP

256	Acc. No 238442	7.9	65.7	6.3	310.2	177.2	21.2	12.6	4.5	73.3	110.3	27.6	44.8	21.2
257	Acc. No 241705	9.7	79.7	8.8	506.7	154.1	17.8	14.2	6.3	87.8	126.3	44.1	31.6	66.1
258	Acc. No 202508	11.2	70.6	8.5	448.2	207.2	19.6	14.3	5.4	81.9	128.1	41.9	32.4	54.2
259	Acc. No 241718	9.4	69.2	7.7	406.1	299.7	22.5	19.4	6.9	108.9	145.6	25.4	27.9	58.1
260	Acc. No 238427	10.3	62.9	7.5	354.9	220.2	16.1	19.5	5.7	80.9	113.1	49.4	32.5	47.2
261	Acc. No 238449	8.8	67.6	7.5	384.4	152.2	16.8	18.2	5.7	79.4	111.1	49.4	34.7	58.6
262	Acc. No 238450	10.6	62.9	7.0	339.1	187.2	16.9	13.1	4.5	88.4	125.6	55.9	30.4	25.7
263	Acc. No 239217	11.3	76.9	8.2	462.0	239.7	16.3	22.9	5.9	108.9	145.6	31.4	31.1	44.8
264	Acc. No 235611	9.1	69.7	7.6	393.9	168.5	22.5	15.6	5.5	79.4	111.1	28.4	31.3	33.5
265	Acc. No 235615	12.8	79.0	7.7	457.6	232.2	14.3	16.6	9.1	107.4	140.6	41.4	29.6	70.6
266	Acc. No 241714	14.2	68.8	7.6	394.4	267.2	16.5	16.8	9.1	111.4	152.1	33.9	31.2	37.9
267	Acc. No 235929	8.3	69.4	8.3	428.5	174.2	18.5	20.7	7.0	77.4	120.6	71.4	37.3	70.6
268	Acc. No 235930	8.2	62.9	6.9	331.4	183.7	22.6	18.7	6.4	74.4	119.1	29.9	35.9	43.2
269	Acc. No 213017	10.7	68.4	9.1	456.0	177.4	17.3	19.8	8.5	91.9	128.6	39.9	31.7	56.2
270	Acc. No 239165	13.9	77.6	7.9	460.9	267.3	18.3	23.1	6.2	107.4	150.6	60.4	31.7	64.4
271	Acc. No 237264	12.3	77.6	7.9	444.1	299.2	26.1	17.1	10.9	104.4	150.6	65.9	31.0	78.4
272	Acc. No 204606	11.2	75.1	7.4	416.3	253.2	23.3	17.6	7.0	86.4	131.1	33.4	27.5	39.9
273	Acc. No 242045	14.8	70.9	7.7	414.6	331.2	28.0	16.7	7.7	106.9	152.1	69.4	29.9	69.9
274	Acc. No 239239	11.0	69.1	7.1	370.0	283.7	25.7	18.1	7.5	81.4	125.6	60.9	40.8	91.2
275	Acc. No 238423	9.6	58.7	6.8	311.4	201.7	22.4	17.9	8.4	83.4	113.1	48.9	32.8	76.9
276	Acc. No 234096	7.0	57.8	6.2	278.6	173.4	20.3	21.1	7.1	80.4	120.6	19.9	33.1	34.9
277	Acc. No 241184	12.5	69.4	8.1	419.8	213.6	19.4	14.0	6.5	93.4	143.1	52.4	27.6	84.6
Mean		11.8	71.7	17.4	398.9	230.2	16.4	17.5	6.2	93.2	133.9	57.2	30.4	52.0
LSD (0.05%)		*0.58*	*2.7*	*0.5*	*29.5*	*15.3*	*1.3*	*1.3*	*0.5*	*3.1*	*3.37*	*4.76*	*2.341*	*10.398*

Notes: @ *Quantitative traits abbreviations as indicated in Table 2.*

Appendix 3.One Hundred Sorghum accessions which gave better grain yield per panicle than the best check for 13 quantitative traits

No	Acces.No	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
1	Acc. No 239174	13.8	79.5	7.5	458.7	263.6	21.5	17.3	8.1	109.1	146.6	115.7	29.9	112.2
2	Acc. No 69502	13.1	75.0	7.7	423.5	261.6	18.5	20.0	4.3	108.8	148.8	42.6	22.5	107.2
3	Acc. No 239234	13.7	76.2	7.9	459.0	262.4	21.8	21.2	8.1	85.5	121.6	54.7	35.2	104.8
4	Acc. No 239224	13.2	71.5	8.4	449.4	324.3	17.4	32.0	5.2	117.0	151.3	69.4	26.5	99.7
5	Sorcoll-021/07	12.8	76.7	6.2	362.9	219.2	10.6	15.6	5.2	90.9	123.1	61.3	32.1	91.5
6	Sorcoll-176/07	12.0	74.9	7.2	413.5	241.8	17.9	14.5	5.8	106.8	152.5	29.3	34.7	91.5
7	Acc. No 239239	11.0	69.1	7.1	370.0	283.7	25.7	18.1	7.5	81.4	125.6	60.9	40.8	91.2
8	Sorcoll-022/07	13.6	75.1	6.9	389.3	217.2	12.1	12.8	5.2	90.4	123.1	74.3	29.7	90.2
9	Sorcoll-029/07	11.4	78.5	7.2	429.4	270.7	17.4	24.2	6.6	86.9	123.1	63.3	32.4	89.1
10	Acc. No 241723	10.9	75.2	7.8	456.2	279.9	20.8	32.0	9.1	82.0	134.6	49.7	34.4	88.7
11	Acc. No 238441	10.2	65.8	7.3	400.1	182.4	13.2	19.7	7.6	76.0	112.1	36.2	31.2	85.3
12	Acc. No 241709	12.3	71.4	7.8	426.1	270.9	14.3	18.9	6.8	95.5	131.6	22.2	35.0	84.8
13	Acc. No 241184	12.5	69.4	8.1	419.8	213.6	19.4	14.0	6.5	93.4	143.1	52.4	27.6	84.6
14	Acc. No 239166	12.8	72.6	7.6	411.3	287.4	20.1	20.9	5.5	109.3	151.5	69.4	26.8	82.1
15	Acc. No 239152	13.8	81.4	6.8	413.9	317.1	16.8	19.8	9.2	110.5	149.8	80.9	30.0	81.7
16	Acc. No 241712	11.1	79.4	8.3	503.7	273.6	27.8	22.0	5.4	116.1	147.6	49.7	33.6	81.1
17	Acc. No 234056	13.7	82.3	9.1	569.5	309.6	18.1	17.6	6.6	113.6	154.1	46.7	28.4	78.9
18	Acc. No 237264	12.3	77.6	7.9	444.1	299.2	26.1	17.1	10.9	104.4	150.6	65.9	31.0	78.4
19	Acc. No 235608	11.1	71.4	8.8	474.4	235.6	14.3	13.5	6.1	95.8	139.0	61.1	27.2	78.4
20	Acc. No 241715	12.5	84.1	7.2	440.1	271.6	16.1	15.4	5.5	109.3	141.3	47.1	28.0	76.9
21	Acc. No 238423	9.6	58.7	6.8	311.4	201.7	22.4	17.9	8.4	83.4	113.1	48.9	32.8	76.9
22	Acc. No 241720	12.9	73.2	6.5	363.0	215.0	20.3	14.6	6.4	80.0	120.8	62.3	27.2	76.4
23	Acc. No 241719	10.9	71.6	8.2	440.6	206.1	11.1	26.1	6.4	108.8	149.0	13.1	28.2	74.7
24	Acc. No 241725	10.7	72.6	8.5	475.8	218.4	19.6	21.5	6.6	78.0	112.1	45.7	37.4	74.7
25	Acc. No 210918	13.5	72.9	6.4	353.6	215.5	19.5	17.0	7.6	100.0	145.8	98.3	29.5	74.4
26	Sorcoll-027/07	9.1	65.2	6.5	317.1	235.2	19.8	18.8	6.7	83.4	113.6	55.8	29.7	74.2
27	Sorcoll-045/07	11.5	66.1	6.7	327.6	242.6	22.9	23.8	8.8	86.3	117.5	74.9	39.1	74.1
28	Acc. No 235607	11.6	72.2	6.7	374.0	178.5	14.5	13.2	5.8	81.0	122.8	58.8	28.9	74.0
29	Acc. No 69510	12.2	74.1	8.1	456.1	283.1	14.9	19.0	7.1	105.8	149.0	46.1	22.3	73.4
30	Acc. No 239242	12.1	71.3	7.8	407.2	255.6	22.8	15.4	5.9	83.8	123.3	92.1	31.9	73.1

Appendix 3.Continued…

No	Acces.No	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
31	Acc. No 239199	12.3	79.0	8.6	510.7	360.1	27.2	48.4	6.3	110.6	146.6	44.7	23.4	72.6
32	Sorcoll-033/07	10.4	72.8	7.1	387.1	272.2	20.4	24.3	8.0	89.9	127.6	66.8	34.0	71.9
33	Acc. No 235929	8.3	69.4	8.3	428.5	174.2	18.5	20.7	7.0	77.4	120.6	71.4	37.3	70.6
34	Acc. No 235615	12.8	79.0	7.7	457.6	232.2	14.3	16.6	9.1	107.4	140.6	41.4	29.6	70.6
35	Acc. No 239157	13.6	85.0	8.4	537.4	271.6	21.9	13.2	6.2	110.6	149.1	46.2	25.6	70.5
36	Acc. No 213005	13.6	72.3	8.4	469.3	210.6	14.2	22.3	5.7	113.6	154.1	50.7	26.9	70.3
37	Acc. No 235618	11.8	70.9	7.9	418.9	247.4	19.2	23.0	5.9	110.5	149.8	24.4	30.6	70.2
38	Acc. No 241728	10.8	68.2	7.5	397.5	313.6	23.7	14.4	14.1	90.1	124.1	43.2	36.3	70.1
39	Sorcoll-276/07	12.7	79.4	7.6	459.5	238.6	20.5	15.6	8.4	106.6	154.9	69.2	25.6	70.0
40	Acc. No 242045	14.8	70.9	7.7	414.6	331.2	28.0	16.7	7.7	106.9	152.1	69.4	29.9	69.9
41	Sorcoll-145/07	11.6	69.8	7.5	374.7	223.7	13.6	10.1	3.7	86.0	133.4	56.4	27.2	69.5
42	Acc. No 241706	10.3	73.6	8.1	454.4	160.1	16.9	17.2	8.6	78.8	109.5	71.1	27.9	69.5
43	Acc. No 213028	12.4	67.7	6.2	307.9	240.5	15.6	16.1	7.3	115.5	140.8	41.3	21.1	69.1
44	Acc. No 238421	12.7	79.2	8.1	476.9	270.8	17.1	19.1	6.7	101.0	151.3	55.4	42.8	68.4
45	Sorcoll-162/07	10.5	69.2	7.1	380.9	180.6	14.0	14.6	3.9	87.8	124.5	63.8	29.4	68.1
46	Acc. No 239222	10.8	71.1	8.4	439.1	368.4	16.8	25.0	5.3	103.8	141.5	51.9	26.6	67.7
47	Sorcoll-078/07	12.4	72.6	8.0	420.5	256.2	15.5	15.5	5.6	91.0	127.5	59.2	33.3	67.3
48	Sorcoll-019/07	12.9	72.5	7.4	408.3	221.7	12.2	19.0	7.7	90.9	127.6	61.3	34.5	67.2
49	Sorcoll-147/07	13.5	76.8	9.4	522.8	190.2	11.9	17.6	5.8	97.5	140.4	46.9	31.7	66.6
50	Acc. No 239221	11.8	77.4	8.9	538.3	330.6	20.9	20.1	6.8	116.6	155.6	67.2	27.8	66.5
51	Sorcoll-258/07	12.2	78.4	7.8	462.3	214.6	17.9	16.8	8.7	90.6	140.4	67.7	26.4	66.4
52	Sorcoll-107/07	12.7	80.0	7.6	436.3	278.7	15.6	9.6	6.4	96.0	147.0	69.2	26.3	66.1
53	Acc. No 241705	9.7	79.7	8.8	506.7	154.1	17.8	14.2	6.3	87.8	126.3	44.1	31.6	66.1
54	Sorcoll-034/07	9.6	61.0	7.4	336.4	168.7	13.5	17.2	6.4	78.9	123.1	39.3	23.2	66.0
55	Acc. No 239236	12.1	76.5	9.4	550.4	275.9	20.6	16.8	8.6	89.0	148.6	64.7	30.5	65.9
56	Sorcoll-127/07	11.6	74.1	7.6	399.5	238.2	11.4	12.9	6.2	85.0	140.9	55.4	31.4	64.7
57	Acc. No 234095	10.0	69.2	6.5	339.4	234.4	22.6	26.0	6.2	76.3	133.5	47.9	34.0	64.6
58	Acc. No 241727	12.7	72.6	7.5	422.8	350.9	13.7	25.9	5.0	116.0	149.6	67.7	27.6	64.6
59	Acc. No 238401	11.9	75.8	7.6	442.5	255.4	15.0	19.3	7.0	82.0	119.6	65.2	48.4	64.4
60	Acc. No 239165	13.9	77.6	7.9	460.9	267.3	18.3	23.1	6.2	107.4	150.6	60.4	31.7	64.4

Appendix 3.Continued…

No	Acces.No	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
61	Acc. No 241707	13.4	77.2	8.3	470.2	300.1	9.6	18.0	4.1	115.3	148.8	16.1	26.1	63.8
62	Sorcoll-031/07	11.1	59.6	7.0	308.0	224.7	17.2	26.3	7.4	82.9	113.6	62.8	34.6	63.6
63	Acc. No 238402	10.8	69.3	9.3	489.6	184.6	13.9	23.3	4.8	91.6	126.1	72.2	32.9	63.2
64	Sorcoll-274/07	12.1	80.6	7.3	448.5	229.4	20.0	17.0	8.4	99.6	142.9	84.7	21.4	63.0
65	Sorcoll-112/07	13.8	71.9	7.3	378.7	267.2	12.9	8.7	7.6	94.0	147.0	61.2	26.2	63.0
66	Sorcoll-214/07	12.8	85.0	6.3	408.0	226.4	12.9	22.2	5.9	117.0	139.9	67.3	29.8	62.7
67	Acc. No 238425	10.9	64.8	5.6	289.7	246.9	20.8	30.0	6.9	80.0	119.6	77.2	26.3	62.3
68	Sorcoll-006/07	12.0	71.2	7.2	388.5	249.7	17.1	19.1	6.8	87.9	125.6	59.3	32.4	62.3
69	Sorcoll-143/07	12.4	71.9	7.1	359.0	226.7	14.9	10.0	4.6	91.5	145.4	59.4	28.9	62.2
70	Sorcoll-111/07	14.3	68.8	7.8	390.8	248.2	14.5	9.7	5.8	93.5	141.5	48.2	28.2	62.1
71	Sorcoll-094/07	13.7	74.1	7.8	414.9	256.2	13.2	12.3	6.5	96.5	142.0	53.2	30.1	61.8
72	Acc. No 237275	13.2	73.8	6.8	375.7	254.0	17.9	19.6	5.7	80.0	119.3	29.8	30.8	61.5
73	Acc. No 235463	11.5	70.1	6.7	349.0	268.8	19.3	23.8	5.6	78.5	127.8	67.9	37.7	60.6
74	Acc. No 239208	13.7	73.8	6.7	374.0	303.8	25.4	25.0	9.3	90.0	139.8	37.9	38.2	60.2
75	Sorcoll-148/07	11.9	76.8	8.2	452.4	184.2	13.5	18.5	6.5	100.5	140.4	71.9	30.7	59.7
76	Sorcoll-179/07	10.6	69.4	8.0	434.2	267.1	15.7	21.0	5.2	106.8	152.5	64.3	28.6	59.4
77	Sorcoll-185/07	8.6	69.7	8.1	435.9	221.7	23.9	17.4	5.2	95.8	133.0	36.3	31.1	59.4
78	Acc. No 225839	14.2	87.2	7.6	513.3	221.0	13.1	13.9	6.9	112.0	140.8	53.8	26.4	58.7
79	Acc. No 238449	8.8	67.6	7.5	384.4	152.2	16.8	18.2	5.7	79.4	111.1	49.4	34.7	58.6
80	Acc. No 239237	11.0	58.6	6.3	304.9	213.4	21.6	22.5	8.2	71.0	109.6	75.2	24.9	58.6
81	Sorcoll-080/07	13.4	75.2	7.2	386.9	265.7	17.8	7.9	5.8	97.5	149.5	58.7	30.9	58.5
82	Sorcoll-273/07	10.7	80.8	8.2	498.0	245.6	20.4	16.0	7.9	99.6	145.9	62.2	27.1	58.4
83	Sorcoll-039/07	12.4	62.5	7.9	372.0	217.6	16.2	19.4	7.6	82.8	121.5	60.4	33.4	58.4
84	Sorcoll-232/07	10.8	64.5	7.4	357.8	171.9	15.6	17.1	6.8	81.0	120.9	53.3	33.9	58.3
85	Acc. No 241718	9.4	69.2	7.7	406.1	299.7	22.5	19.4	6.9	108.9	145.6	25.4	27.9	58.1
86	Acc. No 235623	11.6	74.5	6.3	356.1	298.9	14.3	19.5	4.7	106.8	76.5	62.4	30.2	58.0
87	Sorcoll-198/07	12.4	76.9	5.9	347.2	233.4	14.9	21.2	6.6	106.5	137.9	75.3	29.4	57.9
88	Acc. No 235928	12.1	79.8	6.9	416.4	236.6	11.7	22.3	7.9	109.3	150.1	87.6	33.3	57.8
89	Sorcoll-272/07	9.1	68.9	8.6	450.6	182.6	17.0	19.7	7.2	86.1	123.4	62.2	28.0	57.8

Appendix 3.Continued…

No	Acces.No	LN	L	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
90	Sorcoll-016/07	12.2	70.0	7.2	378.5	234.2	20.3	19.9	7.7	87.4	125.6	104.3	30.5	57.6
91	Acc. No 69505	12.3	73.0	8.1	445.9	259.8	15.8	20.5	5.4	80.0	127.8	59.4	29.5	57.6
92	Sorcoll-093/07	12.2	75.7	8.0	441.5	213.7	12.5	10.6	8.1	89.5	130.0	87.2	25.4	57.1
93	Acc. No 210917	16.6	71.8	7.2	370.0	295.6	14.6	13.0	5.2	112.3	152.8	41.1	28.1	57.0
94	Sorcoll-099/07	12.9	76.1	9.6	539.2	203.2	14.8	18.3	7.2	88.0	130.0	76.7	26.5	57.0
95	Acc. No 69190	12.8	76.5	7.3	424.1	311.8	29.3	22.4	8.4	107.0	83.8	84.4	31.0	56.9
96	Sorcoll-194/07	11.3	69.3	7.0	371.7	206.1	12.5	20.8	5.2	98.3	148.0	52.8	36.9	56.9
97	Sorcoll-014/07	11.4	68.9	6.9	354.6	249.2	15.6	19.2	6.0	86.4	123.1	57.3	31.3	56.8
98	Acc. No 237274	11.8	73.7	6.9	375.5	260.4	19.2	16.7	6.7	83.8	126.5	60.4	39.7	56.6
99	Sorcoll-091/07	14.0	71.5	8.4	435.8	226.2	14.4	9.0	6.5	99.5	149.5	56.7	28.0	56.4
100	Sorcoll-038/07	12.4	66.9	8.0	400.6	236.1	14.3	21.0	6.3	87.3	121.0	53.4	33.3	56.2
Best st. Check(Meko)		*10.4*	*68.3*	*7.4*	*381.4*	*192.4*	*13.9*	*16.6*	*5.9*	*87.9*	*128.3*	*59.9*	*30.0*	*54.5**
LSD (0.05%)		*0.58*	*2.7*	*0.5*	*29.5*	*15.3*	*1.3*	*1.3*	*0.5*	*3.1*	*3.37*	*4.76*	*2.341*	*10.398*

Notes: @ *Quantitative traits abbreviations as indicated in Table 2.*

Appendix 4. Sorghum accessions considered for single plant selection at Melkasa and their Mean performance for 13 Quantitative traits.

No	Accessions No.	Origin	**LN**	**LL**	**LW**	**LA**	**PH**	**IL**	**PL**	**PW**	**DF**	**DM**	**NPBP**	**TSWt**	**GYPP**
1	Sorcoll-044/07	Tigray	14.6	86.1	8.6	551.0	227.6	26.6	20.3	9.4	96.5	152.8	57.7	43.8	66.9
2	Sorcoll-047/07	Tigray	17.6	84.5	7.1	446.8	252.6	23.2	17.5	9.6	68.5	133.8	37.7	40.2	91.4
3	Sorcoll-048/07	Tigray	18.4	83.5	7.7	479.0	332.6	20.8	18.1	11.5	68.5	162.8	59.7	39.1	78.1
4	Sorcoll-049/07	Tigray	16.4	73.1	7.8	421.5	231.6	17.2	20.3	7.3	84.5	147.8	55.7	43.8	42.8
5	Sorcoll-087/07	Tigray	15.4	70.5	8.9	461.4	275.1	19.4	25.3	7.6	68.3	147.5	74.4	36.1	73.4
6	Sorcoll-096/07	Tigray	14.4	84.9	8.6	528.5	199.1	13.6	22.9	7.9	81.3	132.5	64.4	38.4	79.4
7	Sorcoll-099/07	Tigray	13.8	73.3	8.2	431.6	195.1	16.0	19.1	7.4	88.3	139.5	79.4	36.1	63.7
8	Sorcoll-107/07	Tigray	13.4	80.9	7.1	408.9	283.1	17.4	10.1	6.4	94.3	163.5	79.4	32.5	81.7
9	Sorcoll-116/07	Tigray	14.6	84.0	7.8	470.0	295.6	21.6	11.3	6.1	104.8	155.5	38.7	33.9	66.4
10	Sorcoll-117/07	Tigray	15.2	72.6	8.5	452.8	331.6	21.8	12.3	6.3	104.8	155.5	56.7	49.2	72.5
11	Acc. No 237311	Tigray	16.1	74.0	7.4	385.1	255.8	20.3	20.2	8.4	91.5	146.5	49.9	32.9	92.4
12	Acc. No 238441	Tigray	13.8	85.4	9.0	584.1	221.6	14.0	20.5	7.6	73.0	123.0	40.9	30.9	97.5
13	Acc. No 241728	Tigray	12.3	70.1	7.0	413.6	291.8	24.5	14.1	15.1	92.5	139.3	46.7	37.2	64.0
14	Acc. No 238440	Tigray	9.7	71.5	9.0	518.9	147.8	12.9	24.5	7.8	72.5	117.3	48.7	22.8	107.6
15	Acc. No 242044	Tigray	16.6	78.9	8.9	531.3	387.3	24.0	17.8	8.5	102.0	164.3	48.2	41.2	104.6
16	Sorcoll-125/07	Wello	9.2	60.6	6.4	271.7	102.6	9.6	15.1	5.6	70.8	121.5	37.7	29.2	39.2
17	Sorcoll-131/07	Wello	14.4	74.6	7.5	397.2	231.6	16.8	8.7	6.3	87.8	155.5	50.7	37.4	50.8
18	Sorcoll-132/07	Wello	10.8	67.0	7.4	354.3	149.6	13.8	19.5	7.2	70.8	122.5	31.7	37.4	71.7
19	Sorcoll-137/07	Wello	13.8	73.4	7.2	377.7	223.6	16.2	13.5	6.0	107.8	141.5	20.7	28.0	42.1
20	Sorcoll-140/07	Wello	12.4	77.4	6.8	380.1	233.6	15.2	11.9	4.4	94.8	141.5	72.7	30.4	26.6
21	Sorcoll-147/07	Wello	15.6	75.8	8.9	495.1	173.6	11.6	18.8	5.9	104.8	155.5	52.7	37.4	96.6
22	Sorcoll-148/07	Wello	14.8	74.6	7.6	414.3	164.6	14.0	20.5	6.6	110.8	155.5	72.7	37.4	72.4
23	Sorcoll-160/07	Wello	14.7	80.3	6.9	420.6	282.1	15.6	17.0	5.7	102.8	169.8	74.2	40.7	63.9
24	Sorcoll-165/07	Wello	9.7	65.9	7.4	372.9	209.1	16.4	20.1	4.9	82.8	140.8	65.2	39.5	35.2
25	Sorcoll-169/07	Wello	14.7	83.1	8.8	556.2	172.1	15.6	20.4	6.4	99.8	154.8	64.2	37.2	57.6

Appendix 4. Continued...

No	Accesion No.	Origin	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
26	Sorcoll-180/07	Wello	16.1	72.5	7.2	394.3	284.1	14.2	22.6	5.9	107.8	154.8	34.2	44.2	86.4
27	Sorcoll-184/07	Wello	14.1	81.9	8.2	506.7	341.1	19.6	16.8	6.9	111.8	164.8	78.2	38.3	73.2
28	Sorcoll-194/07	Wello	14.3	71.3	7.6	408.0	265.1	13.4	21.6	5.3	107.8	169.8	58.2	47.8	67.4
29	Acc. No 239227	Wello	14.4	81.2	9.0	562.6	244.1	18.8	16.2	9.8	91.3	160.0	55.4	30.3	69.4
30	Acc. No 239223	Wello	14.0	85.2	8.6	560.5	398.1	25.5	26.6	5.7	110.3	167.8	41.2	29.0	97.6
31	Acc. No 239162	Wello	14.6	83.6	8.4	539.5	350.1	26.7	21.0	9.5	93.3	162.8	64.2	42.7	103.6
32	Acc. No 239240	Wello	12.8	81.2	7.2	448.8	198.1	9.3	22.6	5.6	98.3	146.8	60.2	45.7	40.1
33	Acc. No 239222	Wello	12.6	71.3	9.7	523.9	408.1	17.9	26.2	5.3	107.3	152.8	52.2	32.5	77.7
34	Acc. No 239174	Wello	13.1	81.1	8.8	577.0	289.8	22.5	17.9	8.4	100.5	153.3	144.7	38.4	107.5
35	Acc. No 239193	Wello	13.6	75.0	8.5	468.9	309.6	15.5	23.5	8.3	106.3	160.3	60.7	40.8	71.1
36	Acc. No 239242	Wello	14.1	71.9	8.6	449.9	293.3	23.6	16.2	6.0	80.5	129.5	89.2	36.1	106.5
37	Acc. No 239165	Wello	16.2	80.9	7.6	462.2	309.3	19.2	24.6	6.3	107.0	164.3	70.2	42.4	73.2
38	Acc. No 235608	Gamo Gofa	13.6	70.2	8.3	449.7	228.1	14.6	14.0	6.3	102.3	150.0	65.4	31.5	55.5
39	Acc. No 241706	Gamo Gofa	11.0	79.6	9.3	568.2	155.1	17.0	18.2	9.0	75.3	120.0	73.4	33.8	94.3
40	Acc. No 69178	Gamo Gofa	14.5	83.1	8.1	544.1	202.8	13.5	17.1	8.0	104.5	168.3	52.7	40.7	100.0
41	Acc. No 241710	Gamo Gofa	9.7	67.5	7.3	427.1	141.8	18.5	17.9	5.7	105.5	153.3	58.7	27.8	41.4
42	Acc. No 213008	Gamo Gofa	13.3	87.9	8.0	511.9	146.3	11.6	16.6	4.7	93.5	155.5	22.2	34.9	54.7
43	Acc. No 235615	Gamo Gofa	15.6	85.5	8.7	560.3	260.3	15.2	17.4	9.3	102.0	149.3	39.2	35.1	71.1
44	Acc. No 213017	Gamo Gofa	13.4	76.1	7.5	430.6	188.3	18.2	21.2	8.7	89.0	135.3	43.2	42.4	69.1
45	Acc. No 241184	Harerge	15.6	72.9	8.6	466.3	214.3	20.4	15.0	6.5	97.0	149.3	57.2	29.9	77.3
46	Sorcoll-203/07	Kemise	15.3	81.2	7.9	470.3	272.1	12.9	23.6	7.4	111.5	148.0	75.9	38.2	47.5
47	Sorcoll-274/07	Kemise	14.2	82.7	7.2	450.5	240.6	20.8	17.8	8.4	94.8	150.5	88.2	28.0	70.2
48	Sorcoll-279/07	Kemise	13.0	75.7	8.3	479.1	162.6	21.4	15.0	7.2	83.8	126.5	0.2	27.0	64.5
49	Sorcoll-232/07	Shewa	12.5	64.6	6.9	319.9	144.1	15.5	18.0	6.8	81.5	118.0	56.9	42.9	56.1
50	Sorcoll-234/07	Shewa	14.9	77.0	6.3	350.3	209.1	8.9	21.6	6.2	97.5	148.0	47.9	39.4	81.5
51	Sorcoll-249/07	Shewa	13.6	80.5	7.1	428.9	249.6	20.8	13.6	6.7	116.8	166.5	38.2	35.1	53.2
52	Sorcoll-250/07	Shewa	13.2	72.9	7.9	439.9	161.6	20.0	17.7	6.6	80.8	126.5	45.2	52.8	58.4

Appendix 5. Potentials Sorghum accessions considered for single plant selection at Dera and their Mean performance for 13 Quantitative traits.

No	Accession No.	Orgin	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
1	Sorcoll-134/07	Wello	10.6	54.4	8.5	335.2	246.8	12.9	13.5	5.5	83.3	120.2	50.2	20.1	61.8
2	Sorcoll-135/07	Wello	12.6	57.8	7.3	295.9	257.8	15.9	13.7	6.0	86.3	120.2	65.2	32.1	51.1
3	Sorcoll-143/07	Wello	11.8	72.0	7.1	354.7	253.8	14.1	9.9	5.0	86.3	135.2	58.2	26.3	76.2
4	Sorcoll-145/07	Wello	10.2	66.8	7.5	353.7	255.8	12.9	9.4	3.5	81.3	125.2	51.2	24.1	76.9
5	Sorcoll-150/07	Wello	10.0	72.8	7.9	405.4	244.8	14.3	13.7	4.7	85.3	126.2	86.2	17.0	46.9
6	Sorcoll-162/07	Wello	6.9	64.4	6.4	322.8	169.1	13.7	13.8	3.8	89.8	120.2	63.5	18.1	73.7
7	Sorcoll-165/07	Wello	6.9	60.8	7.8	374.3	201.7	15.3	18.5	4.6	82.8	125.2	60.5	30.6	76.7
8	Sorcoll-166/07	Wello	6.9	69.6	9.6	525.0	191.1	13.5	11.4	4.0	82.8	125.2	51.5	22.1	79.1
9	Sorcoll-178/07	Wello	9.1	73.8	7.4	426.1	196.1	13.5	13.0	4.6	89.8	124.2	37.5	37.1	67.2
10	Acc. No 239243	Wello	10.1	65.5	7.9	382.5	220.2	14.2	8.8	5.8	88.3	112.0	48.7	32.0	62.7
11	Acc. No 239238	Wello	9.6	60.0	5.2	222.1	242.8	13.6	17.0	4.4	80.3	120.2	68.7	28.8	68.1
12	Acc. No 239166	Wello	11.0	73.8	7.2	385.5	289.8	19.2	19.8	5.4	111.3	135.2	58.7	18.7	68.5
13	Acc. No 239239	Wello	8.7	64.0	6.8	328.3	266.1	24.5	16.9	7.3	84.8	128.0	57.7	42.8	85.1
14	Sorcoll-001/07	Tigray	8.8	66.4	7.6	377.8	258.9	11.8	13.3	4.6	91.0	120.2	53.7	27.2	69.1
15	Sorcoll-002/07	Tigray	10.2	65.2	8.3	401.8	195.9	8.0	10.8	5.7	91.0	123.2	60.7	23.9	30.8
16	Sorcoll-008/07	Tigray	8.6	63.4	5.9	279.2	228.9	15.8	13.1	5.1	84.0	120.2	58.7	22.2	42.0
17	Sorcoll-045/07	Tigray	10.0	54.7	6.1	225.8	265.6	21.3	22.0	8.6	88.0	101.2	70.2	34.5	70.2
18	Sorcoll-061/07	Tigray	9.6	59.9	7.5	329.0	213.6	18.9	16.2	4.9	92.0	130.2	61.2	21.4	56.7
19	Sorcoll-075/07	Tigray	11.2	47.1	9.1	322.9	186.6	16.5	18.0	6.4	87.0	120.2	69.2	29.5	59.8
20	Acc. No 238439	Tigray	10.5	71.1	6.6	347.0	196.2	17.6	17.5	6.6	79.3	108.0	47.7	38.1	40.0
21	Acc. No 238447	Tigray	7.4	44.8	5.8	216.6	135.3	12.3	16.5	5.2	81.0	120.2	38.5	41.6	42.5
22	Acc. No 238401	Tigray	10.4	82.0	7.5	469.1	312.3	14.1	17.9	7.0	88.0	120.2	61.5	57.7	82.8
23	Acc. No 238441	Tigray	6.6	46.2	5.6	216.0	143.3	12.3	18.9	7.7	79.0	101.2	31.5	31.6	73.0
24	Acc. No 241728	Tigray	9.3	66.3	7.9	381.4	335.4	22.8	14.7	13.1	87.8	109.0	39.7	35.4	76.3
25	Acc. No 238443	Tigray	6.3	70.5	7.4	380.6	187.4	12.4	16.1	5.3	79.8	116.0	63.7	28.8	39.8
26	Acc. No 237285	Tigray	12.5	65.3	8.5	394.2	195.8	6.5	13.8	5.3	118.0	127.0	67.0	32.7	42.6
27	Acc. No 238449	Tigray	6.5	60.4	6.8	310.2	166.1	16.7	16.9	5.6	83.8	103.0	42.7	27.1	64.1
28	Acc. No 242045	Tigray	13.1	62.6	6.9	323.4	308.1	26.5	15.3	7.6	122.8	137.0	60.7	28.1	62.1
29	Sorcoll-272/07	Kemise	6.7	65.0	8.8	429.8	164.6	16.1	18.3	7.1	88.5	120.2	58.2	24.5	53.0
30	Sorcoll-273/07	Kemise	7.7	76.4	8.8	505.1	221.6	19.5	15.5	7.7	104.5	135.2	60.2	21.5	46.2

Appendix 5. Continued...

No	Accesion No.	Orgin	LN	LL	LW	LA	PH	IL	PL	PW	DF	DM	NPBP	TSWt	GYPP
31	Sorcoll-277/07	Kemise	9.5	73.2	7.3	403.9	227.6	25.9	12.3	5.5	88.5	120.2	43.2	19.5	27.8
32	Acc. No 202508	Harerge	8.3	67.4	9.2	461.7	235.1	19.3	13.7	5.8	88.8	137.0	36.7	27.1	80.0
33	Acc. No 235929	Gonder	5.1	63.4	7.8	367.6	189.1	19.7	22.7	7.9	79.8	122.0	70.7	34.5	79.4
34	Acc. No 235607	Gamo Gofa	11.0	71.7	6.0	357.9	198.2	13.6	12.5	5.6	81.5	119.0	49.7	26.1	76.0
35	Acc. No 241720	Gamo Gofa	13.8	66.1	5.8	306.4	204.2	19.6	13.5	6.4	82.5	119.0	58.7	26.0	79.7
36	Acc. No 235608	Gamo Gofa	8.5	72.5	9.4	499.2	243.2	14.0	13.1	5.9	89.3	128.0	56.7	22.9	101.2
37	Acc. No 241706	Gamo Gofa	9.5	67.5	6.9	340.6	165.2	16.8	16.3	8.2	82.3	99.0	68.7	22.0	44.6
38	Acc. No 241709	Gamo Gofa	11.2	74.0	7.8	438.1	254.3	13.7	18.1	6.7	91.0	120.2	41.5	32.0	102.5
39	Acc. No 241725	Gamo Gofa	8.6	68.6	7.4	390.4	173.3	18.7	20.7	6.5	80.0	101.2	40.5	41.6	71.9
40	Acc. No 241710	Gamo Gofa	9.3	63.3	5.9	277.6	202.4	16.8	16.7	5.4	79.8	106.0	51.7	18.8	55.0
41	Acc. No 235617	Gamo Gofa	11.0	80.1	7.0	437.3	274.0	13.6	17.2	7.3	83.8	124.2	64.2	32.8	101.4
42	Acc. No 241715	Gamo Gofa	11.3	85.1	7.7	470.3	287.8	15.7	15.2	5.7	117.0	127.0	43.0	23.4	82.5
43	Acc. No 241705	Gamo Gofa	8.3	78.5	8.9	495.1	174.8	16.9	13.6	6.1	88.0	123.0	37.0	23.6	39.2
44	Sorcoll-229/07	Shewa	10.0	68.9	5.5	306.2	215.8	15.2	12.6	4.4	94.5	118.7	94.7	26.3	49.7
45	Sorcoll-231/07	Shewa	9.4	53.5	7.3	312.5	199.8	12.8	14.8	5.1	80.5	123.7	61.7	27.3	51.9
46	Sorcoll-232/07	Shewa	9.0	64.5	7.9	395.7	199.8	15.6	16.2	6.9	80.5	123.7	49.7	25.0	60.4
47	Sorcoll-239/07	Shewa	10.0	74.1	5.5	324.3	227.8	15.2	13.2	5.3	80.5	117.7	49.7	26.3	58.2
48	Sorcoll-244/07	Shewa	9.5	62.2	7.4	350.1	199.6	15.5	12.5	5.7	114.5	126.2	42.2	28.5	32.5
49	Sorcoll-246/07	Shewa	13.65	86.18	7.34	484.96	250.57	16.17	14.64	7.87	97.64	150.88	76.20	24.67	18.71
50	Sorcoll-258/07	Shewa	8.7	75.0	8.8	502.2	205.6	16.5	16.1	8.5	90.5	130.2	67.2	22.4	66.4

Notes: [@] *Quantitative traits abbreviations as indicated in Table 2.*

Declaration

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in any other University and that all sources of material used for the thesis have been dully acknowlegded.

Dagnachew Bekele __________________________

July 19, 2008

Addis Ababa, Ethiopia